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IS THERE A SURPLUS OF TEACHERS?

A recent government report states that 200,000 certificated teachers in the United States are without jobs. Early in the school year President Roosevelt said: "We have today a large surplus of so-called qualified teachers."

Many people read thus far but no farther and conclude that too much money is being expended on teacher training institutions. Two other important conditions need to be considered along with the statements of the first paragraph. (1) To reduce expenses more pupils are being taught this year and by fewer teachers. Ciasses of fifty or more have become the common practice. If these were reduced to satisfactory conditions for instructions—twenty to twenty-five to a class—so that the teacher could legitimately assume real responsibility for the progress of each pupil or know why no progress was made, the 200,000 surplus would be reduced to a negligible figure. In the commercial world it is the practice to take on employees as business expands; the schools have been forced to operate a rapidly expanding business with a vastly decreased force.

(2) The President did not say there is a surplus of *qualified* teachers. A few years ago the schools could not get a sufficient number of qualified teachers. They took what they could get. Partially trained teachers were put into teaching jobs and gradually worked into permanent teaching positions. Some of these have since made the preparation and adjustments and are now creditable members of the profession. Others have done nothing but hold their jobs and still hold them by tolerance or political preference. There is always a surplus of such teachers just as there is always a surplus of shyster lawyers, quack doctors and

profane preachers. This is the time to set higher standards. When it is necessary to be a university graduate to get a job as a filling station attendant is no time for the schools to accept or retain unqualified teachers. Give the deficient ones now in the profession a limited time to make suitable preparation for the work they are teaching but demand of *all new* teachers at least four years of recognized college work which should include a majority of subject matter courses but sufficient professional courses and practice experience to insure success as an instructor and professional pride. Now is the time to stop assigning the extra algebra class to the foreign language teacher, geography to the athletic coach, and general science to any sort of teacher assisted by the janitor.

The 33rd Meeting of the Central Association of Science and Mathematics Teachers at Chicago, Dec. 1 and 2 showed the continued growth and influence of the organization. The Gold Room of the Congress Hotel was filled for the general sessions and the annual banquet. Next fall the convention goes to Indianapolis with Miss Katharine Ulrich of Oak Park as President and Mr. Joel Hadley of Indianapolis as Vice-president.

It is not the business of the school to teach interesting things but to teach fundamental things in an interesting way.—*A gem from the address of Dean Chas. S. Slichter at the Annual Meeting of the Central Association of Science and Mathematics Teachers.*

"Looking into the future welfare of our country the Legion this year is paying particular attention to the education of the children of the United States. It is an emergency matter.

"Thousands of our schools are closed. They must be reopened. A year of schooling missed at a critical time in a pupil's life may spell the difference between a good citizen and a poor citizen. Too often the pupil who falters for a few months never catches step again in his school work."—Commander Hays, American Legion.

WORDS TO CONFOUND THE PHYSICS STUDENT

By Ross McConnehey

Are you on speaking terms with the following words taken from a recent science program?

Alpha particle	electron	protium
co-electron	photon	positron
negatron	orestron	neuton
deuterium	proton	dueton

FRESHMAN CHEMISTRY IN AMERICA IN 1850

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The latter part of the eighteenth century and the early part of the nineteenth may be said to mark the beginning of modern chemistry. Let us see what had been accomplished up to about 1800. The alchemists had followed their mystical path and had failed to find the Philosopher's Stone, the Universal Medicine or the Alkahest. Paracelsus and Von Helmont had in their blundering way called attention to the application of chemicals to the treatment of disease. The "terra pinguis" of Becher or phlogiston of Stahl had been discredited by Lavoisier but the new conception had not yet been widely accepted. Robert Boyle had been a shining light in urging the separation of science and mysticism and in stressing the value of experimentation. Lavoisier and Bergman had laid the basis for quantitative analysis. Organic chemistry was in its birth throes. Many compounds were known and a few brilliant discoverers had displayed their art. Scheele, for example, had produced a number of organic and of inorganic acids, ferrous ammonium sulfate, chlorine, hydrochloric acid and ammonia. The metallurgy of zinc, iron and steel was fairly well known and the manufacture of glass, sulfuric acid, dyes and of porcelain were upon a comparatively good basis. But when all is said and done chemistry still remained an art. Sound theory was yet unknown.

The year 1800 is not an arbitrarily chosen date. Remember that we have no chemical theory of any consequence extant today, save that of the Conservation of Mass and possibly that of Definite Proportions, that preceded 1800. Dalton promulgated his statement of the Atomic Theory in 1803. It was in 1808 that Gay-Lussac read his paper on combinations of gases before the Societe d'Arcueil. Amadeo Avogadro announced his famous hypothesis in 1811. Prout's idea of the primordial substance bears the date of 1815. Sir Humphrey Davy in 1807 or 1808 gave us the new elements sodium and potassium, produced by the use of the newly-discovered voltaic electricity.

From 1800 to 1850 was a period of intense study and activity in chemical fields. Facts and theory accumulated faster than they could be reconciled. A galaxy of stars who did the bulk of their work during this fifty-year period would read about as follows: Ampere 1775–1836, Berzelius 1779–1848, Bunsen

1811–1899, Dalton 1766–1844, Davy 1778–1829, Dumas 1800–1884, Gay-Lussac 1778–1850, Gerhardt 1816–1856, Graham 1805–1869, Kolbe 1818–1884, Laurent 1807–1853, Liebig 1803–1873, Mitscherlich 1794–1863, Wohler 1800–1882.

The material accomplishments of this period will be touched very lightly; trends of thought will be stressed. Analytical chemistry became thoroughly grounded. Gay-Lussac turned out several quantitative analytical methods. In the derivation of equivalent weights Berzelius himself prepared and analyzed two thousand substances and furthermore inorganic chemistry as a science may be said to date back to him. Faraday in 1834 gave to the world his laws on electrolysis. Bunsen's work on Gasometrische Methoden is still a valuable book. His analysis of blast furnace gases led to the saving of millions in money. Gay-Lussac and Dumas were pioneers in working out methods for measuring vapor density.

Physical chemistry as a science was not born until after this period. Inorganic chemistry prospered. Gay-Lussac and Thenard isolated boron, making use of potassium and sodium which they had learned to make in quantity. Berzelius discovered selenium, cerium and thorium and studied platinum, tellurium, fluorine and sulfur. He impressed his personality upon the whole field of thought in a way never to be forgotten. Dumas studied phosphorus, arsenic and sulfur. Davy separated ammonia into its elements and isolated potassium and sodium, as before mentioned, thus demonstrating the compound nature of the alkalis.

Much was done during these years in the development and organization of organic chemistry, though later progress dimmed in some measure the luster of this period. This was preeminently a battleground of theory. The ground had to be cleared of certain ideas before better ones could come.

The relationship between crystal form and chemical composition was made the subject of study by Mitscherlich. He worked on the similarity of the arsenates and phosphates. It was in repeating these experiments that Pasteur at a later date arrived at his epoch-making discovery on stereoisomerism.

Berzelius was responsible for the Oxygen Theory of Acids. This necessitated the presence of oxygen in each acid and in each base; in neutralizations the ratio of oxygen in the acid to oxygen in the base was a small integral number. The difficulty with hydrochloric acid and ammonia was recognized. Davy's failure to obtain oxygen from chlorine or from dry

muriatic acid, and Gay-Lussac's investigations on hydriodic acid and hydrocyanic acid demonstrated the untenability of the Oxygen Theory. Berzelius in 1820 accepted Gay-Lussac and Dulong's view that there were two classes of acids: (1) oxygen acids, forming salts by direct addition of metallic oxides, and (2) halogen acids, forming salts in the same way that zinc is now considered to form zinc chloride from hydrochloric acid. This did not in itself settle the case of oxygen in ammonia. The quantitative decomposition of ammonia into nitrogen and hydrogen by Henry and Berthollet and the possibility of forming a compound of ammonia with water probably together gave the death blow to this idea.

The theory of Dualism had been in the making since during the life of Lavoisier and it was championed actively by Berzelius. At the height of its authority it represented the combination of substances as consisting in the union of an electropositively and of an electronegatively charged atom or group of atoms. Hydrogen was placed in an intermediate position as to charge, so that it might combine to give either positive or negative substances. Potassium occupied the extremely positive end of the scale and oxygen the negative end. To explain the formation of complex substances such as alum it was assumed that the potassium sulfate was more positive than aluminum sulfate so that there could still be union of the two compounds. This theory would demand that the formula for potassium sulfate be written K_2O, SO_3; aluminum sulfate would be Al_2O_3, 3 SO_3; and alum would be K_2O, $SO_3+Al_2O_3$, 3 SO_3+24 H_2O. According to Dualism the formula for methane was C_2H_8, for acetic acid $C_6H_4O_3$, for grain alcohol $C_4H_{12}O_2$ and for ethyl ether $C_4H_{10}O$.

The brilliant research of Bunsen on the production of free cacodyl and that of Gay-Lussac on prussic acid, demonstrating the cyanogen radical, cast serious doubts upon the Dualistic conceptions. Dumas attacked the theory because of his experiments on the chlorination of acetic acid. The formation of trichloracetic acid gave a compound which, in spite of the great amount of substitution, was still strikingly like acetic acid. Out of this came the first Type Theory. Compounds were, according to this theory, either classified under (1) Chemical types or substances bearing close similarity in chemical relationship, or (2) Mechanical types or substances having a kinship only because of like appearance in formulae. Dumas contended that there was no necessity for an arbitrary and un-

necessary division of a formula as in K_2O, SO_3, thus passing from the idea of Duality to unity.

Extravagant claims for the first Theory of Types led it into obscurity. This was followed by attempts at improvement, such as the Nucleus Theory of Laurent and the Theory of Residues of Gerhardt. The fame of Gerhardt culminated in the second Theory of Types. This is substantially our modern theory of radicals. This theory helped materially in putting formulae upon a correct basis by adopting a system based upon Avogadro's Law. Previously equivalents had been a vague term, formulae being on the "four-volume" basis. Now they were on a "two-volume" basis, meaning that the gram-molecular weight of any gaseous substance occupies the same volume as two gram-atomic weights, or one molecular weight of hydrogen. It is true that Gerhardt and Laurent did not have a perfect instrument and did not appreciate the full value of their theory but it was a splendid approach and led the way to Canizzaro's clear statement in 1858.

Thus has been given briefly the setting of the stage upon which the Freshman entered in 1850. The textbooks of 1850 devote on the average of 24% of the pages to Physics, 48% to Inorganic Chemistry, 3% to Analytical and 27% to Organic. This adds up slightly more than 100% but is explained by the fact that the Analytical is partly Ultimate Analysis, which is included in the Organic percentage.

INORGANIC CHEMISTRY

The texts are agreed on four fundamental laws: (1) Law of Definite Proportions. (2) Law of Multiple Proportions. (3) Law of Equivalent Proportions. "When a body (A) unites with other bodies (*B*, *C*, *D*, etc.) the proportion in which *B*, *C*, and *D* unite with *A* will represent in numbers the proportions in which they will unite among themselves in case such union takes place." (Silliman.) (4) Law of Combining Numbers of Compounds. "The combining proportion of a compound body is the sum of the combining weights of its several elements." (Silliman.) Law No. 3 is considered the "most important law in chemical philosophy." Gay-Lussac's Law of Combining Volumes is recognized, though not so named. The atomic theory is according to the Daltonian conception.

Chemical affinity comes in for considerable discussion. It is defined as the "power which unites two or more unlike bodies to

form a third substance, whose properties differ from those of its constituents." Several points about affinity are noted: (1) It is not equally shared by all bodies and depends largely on conditions. (2) The more unlike any two bodies are the more likelihood of union. (3) Solution is the result of feeble affinity. (4) The circumstances affecting activity are intimate contact among particles, heat, light and electricity. (5) The nascent state favors affinity. (6) Catalysis is a great factor. (7) Gravity has its influence. There are three kinds of affinity: (1) Simple Affinity, as when camphor dissolves in alcohol. (2) Single Elective Affinity. Thus, in the previous case if water is added to the solution, the alcohol leaves the camphor and combines with the water. (3) Double Elective Affinity, involved in all double decompositions.

Various attempts were made to put affinity upon a mathematical and comparative basis. Kane gives us this table.

No. 1 Muriatic acid	No. 2 Sulphuric acid
Oxide of silver	Barytes
Potash	Strontia
Soda	Potash
Barytes	Soda
Strontia	Lime
Lime	Magnesia
Magnesia	Oxide of silver

This shows the relative affinities of the bases for each of the oxides. But the conflict is shown by oxide of silver being the weakest of the bases in one column but the strongest of the number according to the other column. Kane philosophically accepts the situation and says: "Had mere affinity been omnipotent—immediately on the origin of our globe, those bodies which have the most powerful affinities would have satisfied them by entering into eternal union;—and long since all nature would have been arranged into some few chemical compositions, the breaking up of which could not be accomplished by any existing force. The complex changes of animal and vegetable digestion and respiration could not go on; the working of the metals, the chemical arts of civilized life, could not have been invented; and the planet which we inhabit would have revolved in space a barren and uninhabitable ball."

Most of the authors agree on 13 or 14 non-metals and 42 metals. Fownes and Draper each gives 49 metals. Only two—Silliman and Kane—classify the non-metals. They agree as

follows: 1. Oxygen. The only element forming compounds with all others and is electronegative. 2. Chlorine, bromine, iodine and fluorine. Similar in properties. The acid compounds with oxygen are similar and their constitution expressed by RO, RO_4, RO_5, RO_7, where R is an atom of the electropositive body. 3. Sulfur, selenium and tellurium. Formula of the oxygen acids RO_2, RO_3. Nitrogen, phosphorus, arsenic, antimony. Similar compounds with hydrogen. 5. Carbon, silicon, boron. Similar, non-volatile, combustible bases; feeble acids with oxygen, 6. Hydrogen. Kin to the metals.

All give classifications of the metals. Silliman's idea will be given. Class 1. Alkalis. Potassium, sodium, ammonium, lithium. Class 2. Alkaline Earths. Barium, strontium, calcium, magnesium. Class 3. Earths. Aluminum, glucinum, thorium, yttrium, cerium, zirconium, lanthanum (Fownes includes here erbium, terbium, norium, didymium). Class 4. Oxyds form powerful bases. Manganese, iron, chromium, nickel, cobalt, zinc, cadmium, lead, uranium, copper. Class 5. Oxyds are weak bases or acids. Vanadium, tungsten, molybdenum, columbium, titanium, tin, bismuth, antimony, arsenic, osmium (Fownes includes niobium, pelopium, tellurium). Class 6. Noble metals, oxyds reduced by heat alone. Mercury, silver, gold, platinum, palladium, rhodium, iridium (Fownes includes ruthenium).

Kane classifies metals and non-metals in one list on the basis of dimorphism. Draper classifies the metals solely by the difficulty with which they decompose water.

The elements which we do not find in our modern lists are niobium Nb (our columbium), didymium Di (later separated into neodymium and praseodymium); norium No; and pelopium Pe (found to be identical with columbium). Of norium, Fownes says: "Svanberg has rendered it probable that an undescribed metallic oxide exists in certain varieties of zircon, for the metal of which he proposes the name of norium."*

Variations from the modern symbolic notation are: Columbium Cm, glucinum G, lanthanium Ln, lithium L, platinum Pl and rhodium R.

The nomenclature of the period is fairly clear and credit is given to Lavoisier for its advantages. Union of two elements gives a binary compound, but a binary compound with water is called a hydrate. Salts from the union of two compounds are

* EDITOR'S NOTE. Hafnium has since been found in certain varieties of zircon. F. B. W.

called ternary compounds. The union of two salts gives a quaddro- or quaternary-compound. Compounds of chlorine are called chlorides, etc. but compounds of sulfur are sulfurets, of selenium are seleniurets, of tellurium are tellurets, of carbon are carburets, of nitrogen are nitrurets, of phosphorus are phosphurets, and of arsenic are arseniurets. Ic-ate, ous-ite and hypo have the same meaning as now. Salts are neutral if neither acid nor base is in excess, are supersalts if acid predominates, and sub-salts if base prevails. Compounds of oxygen are oxyds or acids; those with the least proportion of oxygen are called protoxyds, though metals ending in um sometimes change um to a to indicate protoxyd; the next degree of oxidation is indicated as bi- or deut-oxyd; the next, tritoxyd; the highest, peroxyd; an "inferior" oxide, suboxyd; proportion of one and a half, sesquioxyd. The following table from Gray illustrates these points:

Triphosphuret of copper	1	equi	P	and 3	equiv	Cu
Dinoxide of copper	1	"	O	and 2	"	Cu
Subsesquiphosphuret	1	"	P	and 1½	"	Cu
Protoxide of copper	1	"	O	and 1	"	Cu
Sesquioxide of manganese	1½	"	O	and 1	"	Mn
Binoxide of manganese	2	"	O	and 1	"	Mn
Teriodide of nitrogen	3	"	I	and 1	"	N
Quadrochloride of nitrogen	4	"	Cl	and 1	"	N
Peroxide of iron	Iron oxidated in the highest degree					

The uncertainty under which this period labored in regard to equivalent and atomic weights is reflected in their formula for water HO. Fownes says: "The expression *atomic* weight is very often substituted for that of *equivalent* weight, and is, in fact, in almost every case to be understood as such: it is, perhaps, better avoided." Silliman says: "As all ponderable matter is assumed to be formed by an aggregation of a series of these atoms, the interesting question at once arises, do the chemical equivalents or combining weights of the several elements express the relative weights of their atoms? Dr. Dalton first proposed the view now generally accepted, which assumes this to be the fact.—Dalton's hypothesis of the relative weights of the ultimate atoms is only theoretical, but has been found to conform to a remarkable degree to the results of experience. —The *atomic* weight of a body is therefore as correct an expression as its *equivalent* weight, or combining proportion."

Two values are given for each element for its equivalent weight, one on the basis of hydrogen equal to one or oxygen equal to eight, the other on the basis of oxygen equal to 100,

the former being preferred. The following elements are given by Silliman approximately one-half the present values for atomic weights: Al, Ba, Cd, Ca, C, Cr, Co, Cu, Au, Ir, Fe, Pb, Mg, Mn, Hg, Mo, Ni, O, Pd, Pt, Rh, Se, Sr, S, Te, Sn, Ti, W, Y, Zn. Those given about one-third the present values are: Bi, Ce and Zr; one-fourth, Th and U; while Be has three times the current value. The various texts do not agree on the values. No equivalent weights are found for Dy, Er, La, Nb, Pe, Ru or Tb.

The division into acids, bases and salts was well recognized, with empirical definitions for each. Fownes lists 57 inorganic acids. Besides the common ones of today he lists such as chlorocarbonic (phosgene), chlorochromic (CrO_2+Cl), chlorosulfuric and iodosulfuric.

The laboratory apparatus and experiments present a fairly modern appearance. There are the customary pneumatic troughs, flasks, ring stands, test tubes, retorts. The "serous membrane of a turkey's craw" is recommended for making a hydrogen balloon. Alembics, Hessian crucibles, blowpipes, lamp furnaces, and bell jars are often used. Experiments are for the most part not listed separately but many are indicated in the body of the text. Chemistry is distinctly an experimental science in this period.

ANALYTICAL CHEMISTRY

Comstock gives rather serious attention to analysis. He gives methods for analyzing mixtures of gases containing oxygen, or hydrogen, or carbonic acid, or hydrogen and other inflammable gases. His methods for the analysis of minerals include marble, earth sulfates, separation of silica, alumina and iron, separation of iron and magnesia, analysis of minerals with fixed alkali. The methods for mineral waters are sketched. Methods for the chemical metallurgy of Au, Ag, Hg, As, Co, Bi, Sb, Pb, Cu, Sn, Zn, Fe, chrome, U, Pt, Mo and Mn are given.

Ultimate analysis of organic compounds uses some methods still current. Carbon and hydrogen are determined by Liebig's method which dates back to 1831 and which is still in use. Nitrogen uses Dumas' method and also that of Will and Warrentrapp. Carius' method was not known. Sulfur is oxidized by concentrated nitric acid or by fusion in a silver vessel with potassium hydrate and nitre. Chlorine from a liquid is estimated by mixing with quicklime and bringing to red heat; the chlorine in the vapor displaces oxygen and gives calcium chloride, in which the chlorine is determined by silver nitrate.

ORGANIC CHEMISTRY

The organic chemistry presented is not nearly so uniform in content nor so systematically given as the inorganic. The various authors do not agree among themselves as to subject matter. A great body of material had been accumulated and some attempt and success in organizing it had been accomplished.

The Doctrine of Substitution, illustrated by the action of chlorine on methane, was in the ascendancy. This marks the downfall of Dualism and the rise of Types. Fownes gives a list of Compound Radicals.

TABLE OF COMPOUND RADICALS

Amidogen	Iridiocyanogen	Acetyle
Oxalyle	Sulphocyanogen	Kakodyle
Cyanogen	Mellone	Methyle
Ferrocyanogen	Uryle	Formyle
Ferridcyanogen	Benzyle	Cetyle
Cobaltocyanogen	Salicyle	Amyle
Chromocyanogen	Cinnamyle	Glyceryle
Platinocyanogen	Ethyle	

Two kinds of formulae were recognized: Empirical and Rational. The former represented the simplest possible expression of the composition. The latter represented one equivalent. Their confusion is illustrated by such formulae as these: cane sugar $C_{24}H_{22}O_{22}$, grape sugar $C_{24}H_{28}O_{28}$, ethyl alcohol $C_4H_2O_2$, tartaric acid $C_8H_4O_{10}+2HO$, and stearic acid $C_{68}H_{66}O_5$, $2H_2O$.

Cases of isomerism were well known but in the absence of constitutional formulae the explanations were not very convincing. Fownes says: "For instance, formic ether and acetate of methyl are isomeric, both containing $C_6H_6O_4$. but then the first is by some supposed to consist of formic acid, C_2HO_3, combined with ether, C_4H_5O; while the second is imagined, in accordance with the same views, to be made up of acetic acid, $C_4H_3O_3$, and the ether of wood-spirit, C_2H_3O. And this method of explanation is generally sufficient and satisfactory: when it can be shown that a difference in composition, or even a difference in equivalent numbers, exists between two or more bodies identical in ultimate composition, the reason of their discordant character becomes to a certain extent intelligible."

The conglomeration of facts in the organic field is illustrated by the classification or lack of classification of the organic com-

pounds. Draper says: "In the present state of organic chemistry, it is impossible to present a perfect system of arrangement, as in inorganic chemistry, or one approaching to the finish of that department." Fownes' classification will be given.

1. Quasi-elementary substances, and their compounds.
2. Organic salt-bases. Vegeto-alkalis.
3. Organic acids. 147 are listed.
4. Neutral non-azotized substances. Sugars, starch, gums, etc.
5. Neutral azotized substances. Albuminous principles and their allies.
6. Carburets of hydrogen, oxides and their derivatives.
7. Fatty bodies.
8. Compound acids.
9. Coloring principles.

SUMMARY

We see that the Freshman of 1850 had a mass of facts in several fields offered him. He had some well-defined theories to guide him, others in a state of flux. We may conclude that he was able to pursue a course possessing distinctly modern tendencies.

Texts consulted were: Comstock's Elements of Chemistry, 1846; Draper's A Textbook of Chemistry, 1853; Fownes-Bridges Elementary Chemistry, Theoretical and Practical, 1850; Gray's Elements of Chemistry, 1848; Kane-Draper's Elements of Chemistry, 1842; and Silliman's First Principles of Chemistry, 1846.

MORE CHILDREN—FEWER TEACHERS

Approximately 200,000 certificated teachers are unemployed; 18,600 fewer teachers, it is estimated, are employed in city schools today than in 1931. Thousands more have been dismissed from private schools and colleges. Small percentages of graduates of teacher training institutions are finding positions.

If we decided to operate city schools today with the same number of pupils to a teacher that we had in 1930, it would be necessary to hire more than 26,000 additional teachers.

If we decided to provide education for the 2,280,000 children 6 to 15 years of age not now in school, it would be necessary to add 76,000 teachers.

Thus, if the United States were really determined to give all of its children the minimum essentials of a modern education, it would be necessary to engage one-half of all certificated teachers now unemployed. Businesses that increase take on more help. School enrollment has increased more than a million since 1930—but the number of teachers, city *and rural*, decreased more than 30,000. Teachers are unemployed, but classes grow larger. One State has 44 pupils per teacher. The average for five States is more than 40. Teachers are unemployed despite the fact that more than 1,500,000 children will this year be taught six months or less.

FORMULAE FOR INTEGRAL SIDED RIGHT TRIANGLES

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The topic of right triangles is easy to develop and of very great interest in many lines of pure and applied mathematics. There is an extensive literature on the subject, both ancient and modern, and it might seem as though there is nothing more to be added. I propose to give in this paper a number of formulae which I have not found in the literature, and if they add to the teacher's equipment or in any way stir up interest in this ancient subject, I shall be happy.

I am quite aware of various formulae for finding the three sides of integral sided right triangles. Some are of the form in which one side is represented by $2n$, a second side by n^2-1, and the third side by n^2+1. These formulae are incomplete, since there are many integral sided right triangles which are not reducible to these terms. Other formulae are represented by $2pqt$, $t(p^2-q^2)$, $t(p^2+p^2)$. These are formed obviously from the well-known theorem about the squares on the sides of a right triangle, and the introduction of the constant t makes them include every triangle. It is not easy, from these formulae, however, to find the exact triangle needed in a given operation, nor is it easy to develop sets of triangles systematically from these formulae. I propose a new line of attack which will clarify the whole field of right triangles and make it easy to manufacture triangles to order as required, to the full extent to which they exist.

The reader may well pause at this point to sharpen his pencil, secure a goodly supply of "scratch paper" and reach for his well-worn volume of mathematical tables, for we shall dive at once into our subject.

Let us begin with the well-known favorite right triangle, 3, 4, 5. Students in elementary courses often discover for themselves that sides of 5, 12, 13, also form a right triangle, and at about the same time they find out, or are told, that 6, 8, 10; 9, 12, 15; 12, 16, 20, and so on, in fact all triangles whose sides are multiples, respectively, of the sides of a right triangle, are also right triangles.

When we have worked out a number of triangles from our tables and sought to arrange them in some systematic form, we

begin to see some definite relations. Consider, for instance, the following series:

3, 4, 5
5, 12, 13
7, 24, 25
9, 40, 41
11, 60, 61
13, 84, 85
15, 112, 113, etc.

It is evident that a regular law can be discovered to connect the various members of this series. The shortest side of each triangle has a numerical value of 2 less than the shortest side of the next larger triangle in the series. The differences between the second sides increase in arithmetical progression, being 8, 12, 16, 20, 24 and 28, and the same relation holds between the hypothenuses. Furthermore, each hypothenuse is numerically larger by 1 than its corresponding side. This latter, we shall see, is for this study the most characteristic property of this series of triangles. This difference we shall call s, and the common property of these particular triangles is expressed when we say that s equals 1.

The second series, in which s equals 2, begins this way:

8, 15, 17
12, 35, 37
16, 63, 65
20, 99, 101
24, 143, 145
28, 195, 197
32, 255, 257, etc.

In the second series, the difference between the shortest sides is 4, as compared with 2 for the first series, the differences between the second sides are 20, 28, 36, 44, and so on, and each hypothenuse is larger than each second side by 2.

The third series has a special interest for us in that each triangle is symmetrical with a triangle in the first series, and this is true for each higher series, at least, to the extent to which our study thus far shows. We shall soon discover, however, a method of fractional interpolation, by means of which every possible integral sided right triangle is ferreted out and brought to light.

A tabulation at this point will bring the matter into perspective and allow me to explain further laws of relation between the triangles. Using again the triangles we have already mentioned, with some omissions and some additions, we have

$s \backslash n$	1	2	3
1	3, 4, 5	5, 12, 13	7, 24, 25
2	8, 15, 17	12, 35, 37	16, 63, 65
3	15, 36, 39	21, 72, 75	27, 120, 123
4	24, 70, 74	32, 126, 130	40, 198, 202
5	35, 120, 125	45, 200, 205	55, 300, 305
6	48, 189, 195	60, 297, 303	72, 429, 435 etc.

In the table just given, the triangles in each horizontal row belong to one series, and each series can be extended indefinitely. Each vertical column, on the contrary, shows the position of each of its triangles with respect to the series, that is the number of each triangle in its own series. Every integral sided right triangle can, then be identified by two quantities, its s and its n. Our task is to associate the s's and the n's into formulae which explain the table and also give the means of extending it indefinitely. These formulae are: (where a, b, and c are the three sides, according to the usual convention, c being the hypothenuse)

$$a = s(2n+s)$$

$$b = \frac{s}{2}(2n+s+1)(2n+s-1)$$

$$c = \frac{s}{2}(2n+s+1)(2n+s-1)+s$$

It is to be noted in connection with these formulae that s and n may have any integral values whatsoever, positive or negative, and n may have in addition the value zero. In using the formulae triangles occur which have negative values for the sides, but these conform in every way to the Pythagorean Theorem, and are true right triangles. Occasionally one of the sides is zero, as, for instance, when s is 1 and n is -1; a is -1, b is 0 and c is 1. If s equals 8 and n is -4; a is 0, b is -4 and c is 4. In all such cases, the resulting "triangle" is a limiting form, and has analytically the properties of a triangle in which one side is of zero magnitude.

An illustration will make clear the use of fractional values in applying the formulae. In the series 8 the following triangles occur for various values of n:

n	a	b	c
1/4	68	285	293
0	64	252	260
−1/4	60	221	229
−1/2	56	192	200
−3/4	52	165	173
−1	48	140	148
−5/4	44	117	125
−3/2	40	96	104
−7/4	36	77	85
−2	32	60	68 etc.

It will be noticed at once that the triangles given above for n-values of $-\frac{1}{4}$, $-\frac{3}{4}$, $-5/4$ and $-7/4$ have sides represented by numbers prime with respect to each other, and, furthermore, for this reason they do not occur with values of s less than 8, or, to put it in another way, these triangles are not similar to triangles occuring in series with lower values of s. By using these fractional values for n we obtain, therefore unique triangles and are able to complete all possible series of integral sided right triangles.

The condition under which fractional forms of n can, and indeed must be used if a complete list is to be obtained, is that the expression $(s/2)(2n+s+1)(2n+s-1)$ is an integer. Fractional forms which n can assume are by no means confined to halves and fourths. For instance, the values 9 for s and $-39/9$ for n give us, quite surprisingly, an old friend in another form, that is, 3, −4, 5. Furthermore, −3, −4, 5 is the triangle in which s is 9 and n is $-14/3$.

It needs to be pointed out that, while n may have fractional values, s cannot. The reason is simply that s represents the difference between the value of the hypothenuse and that of the second side, and since both these quantities are by definition integers, it follows that s must also be an integer. The meaning which attaches to negative values for s is clear from the fact

that the hypothenuse may be represented by a negative number which will be algebraically smaller than either of the sides. Arithmetically the number will be larger. These considerations will prevent confusion in dealing with triangles of this kind.

Extensions of the formulae I have given will shed new light on various problems associated with integral sided right triangles. Such problems are those in which two sides (not including the hypothenuse) are required to differ by a given quantity, or two of the sides must add to a given quantity. The old problem of finding three integral sided right triangles of equal area has now a new approach when we reflect that in terms of our formulae, the area of a right triangle is $(s^2/4)(2n+s+1)(2n+s)(2n+s-1)$ that is, the multiplication of three consecutive numbers (though not necessarily integers) by the fourth part of the square of s.

ELEMENTARY SCIENCE IN IOWA

The Elementary Science Section of the Iowa State Teachers Association held their program and exhibits of books in the General Science Rooms in the Administration Building at Drake University, Des Moines, Iowa, November 3, 1933.

The Program consisted of the following:

1. Pupil demonstration of activities of a Sixth Grade Unit of Science, "Our Solar System," by Gwendolyn Newquist, Sixth Grade pupil, Newton, Iowa.
2. Paper: "The Pleasure a Child Obtains from Nature Study," by Miss Kitty Tiedemann, Supervisor of Nature Study in the Elementary Grades, Burlington, Iowa.
3. Address: "Some Units of Science for the Elementary Grades," (illustrated with lantern slides of pupil activities in studying the units), by Miss Lillian Hethershaw, Head of the General Science Department, Drake University.

Over sixty books for pupils and teachers in the following field were on display:

1. Insects
2. Trees
3. Wild flowers
4. Ships

The officers of the organization were: President; Miss Romaine Startzer Commack, Newton, Iowa. Secretary-Treasurer; Kitty Tiedemann, Burlington, Iowa.

Over one hundred and fifty were in attendance at the program.

This was the second State Program of the Elementary Science Division. There was a very good increase in attendance over that of last year, which would seem to indicate an increasing interest in Science for the elementary grades.

THE MEASUREMENT OF OUTCOMES OF INSTRUCTION OTHER THAN INFORMATION

By Palmer O. Johnson
University of Minnesota, Minneapolis

Means are available for conveying quantitative concepts of the diameter of the Einstein universe or the nucleus of the hydrogen atom, the mass of the galaxy or of the electron, the rate at which the mass of the sun is diminishing or of cosmic ray oscillation, the velocity of light or the speed of diffusion of gold into lead, the hottest stellar interior or absolute zero. But what means are at our disposal for expressing in quantitative terms growth in the functional understanding of the principles of science, in the ability to think scientifically or to use the scientific method, in the development of scientific attitudes or the many other outcomes that are postulated by the teachers of science as the contribution of their instruction? Surely these phenomena transcend others in importance, but as yet their description is chiefly qualitative and will remain such until instruments of measurement have been developed to render them more and more accurately quantitative. The history of science relates many instances where the introduction of new instruments has created new epochs. In fact, the story of science is largely told in terms of the methods of measurement. As theories advance, the experimentalist develops measures to compare anticipated results with experience. Theory and measuring instruments have kept somewhat apace in science, but in the teaching of science the projected outcomes are largely theoretical in character. We are greatly in need of methods by which the attainment of these outcomes may be rendered perceptible. Until this is possible, we shall remain powerless to demonstrate the many claims that are made for the teaching of science. It is the purpose here to point out some small beginnings at measuring outcomes other than information.

An examination of the more commonly used standardized tests or the informal objective tests of the teacher reveals that they are largely concerned with the measurement of the acquisition of more or less detailed information. This is likely the consequence of the emphasis that is placed in courses of study upon the accumulation of details and facts. These courses of study generally consist of topical outlines. Even the deviation noted

a decade ago, when some organizations of content became couched in statements of specific objectives, produced no noticeable change in the instruments of measurement. Nor has the more recent plan of unit organization, attempting to introduce the attainment of major principles of science as major aims, been paralleled by departures from common examination practices. It is not inferred that testing for the acquisition of information is not important, but unless this is held to be the end product of instruction, the other outcomes need to be tested as well. It does appear, however, that unless another approach is made to a measurement program, testing for the acquisition of information will remain the main endeavor. One means of directing attention away from the acquisition of content as the sole aim is to think of aims of instruction in terms of the learner's behavior. For purposes of illustration, references are made to a measurement program now under way in the Junior College of the University of Minnesota under the auspices of the University Committee on Educational Research.

A step of primary importance in inaugurating a measurement program is the listing of course objectives. These are given for the course, Physics and Chemistry, as:

1. The acquisition of certain physical and chemical facts, principles, and a technical vocabulary (specific knowledge).
2. The ability to employ the scientific method.
3. The ability to apply physical and chemical knowledge in the interpretation of everyday experiences.
4. Stimulating an attitude of curiosity or inquiry toward the nature of the physical world.

The question now arises whether or not separate tests are necessary for the respective objectives. If not, then the commonly used test devoted to testing the first of the listed objectives, would appear to suffice. That the attainment of one objective does not assure the attainment of the others will be pointed out by subsequent data. This appears contradictory to the supposition implied in the commonly used test, viz., that if a student acquires a knowledge of vocabulary, facts, and principles the other objectives are automatically attained. The formulation of objectives in specific terms serves to give direction to a measuring program. When stated in terms of the learner's reactions, it becomes necessary to define the behavior of the students who possess the abilities under consideration. In this way a complete registry of student accomplishment must take into

consideration outcomes other than the mere acquisition of information. Some of the abilities to be tested may require performance tests while others need only the commonly used "paper and pencil" tests.

It is not the purpose here to discuss all the technical phases of test construction, but rather to point out a few illustrations from some of the examinations in Junior College science that purport to test certain aspects of functional knowledge. As here interpreted functional knowledge implies the ability of the student to apply the knowledge he possesses to the solution of problems or new situations. This involves the ability to recall information previously acquired, to select those portions relevant to the situation, to realign ideas and synthesize them in a manner affording a basis for interpreting the situation or problem.

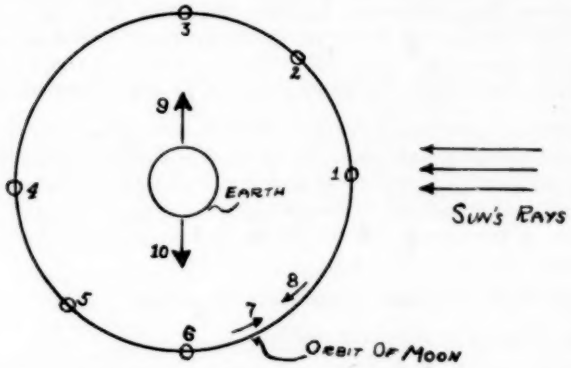
Teachers frequently object to the introduction of questions into an examination that have not been previously answered in class or in other sources of materials of instruction. Obviously such procedure is to place emphasis mainly upon the memorization of information. If we are to test the ability to use knowledge, it is essential to introduce situation or problems to which the student has not been previously exposed. The basis for the interpretation should have been obtained through the materials of instruction or their methods of presentation. If previous exposures have been experienced, then one cannot determine whether or not the response is due to the recall of the answer as given by the teacher, the text book, or other such sources. It is obvious that the number of test situations should be sufficient to afford a reliable sampling and to test various gradations of ability.

Illustrations are drawn first from an examination in Astronomy.

In the diagram, we are looking down from the *north.*

1. Draw, in the diagram, the shadow of the moon as it is at annular eclipse.
2. Represent in the diagram how a lunar eclipse occurs.
3. Indicate by the number on the diagram:
   ( ) new moon
   ( ) first quarter
   ( ) full moon
   ( ) crescent moon
   ( ) direction of moon's motion
   ( ) direction of earth's motion

4. At a solar eclipse the moon must be at ( ).
5. At a lunar eclipse, the moon must be at ( ).
6. When the moon rises at sunset, it is at ( ).
7. When the moon is seen in the west in the forenoon, it is at ( ).
8. Earthshine is noticeable when the moon is at ( ).
9. Venus at inferior conjunction appears the same as the moon at ( ).



In some instances the modified true-false type of test may serve to test for functional knowledge. In this type, the student is asked to state whether a given statement is true or false and, if he considers it false, to cross out the term or terms that make the statement false and give the correct terms. Words that are italicized are not to be changed, i.e.:

If the *eccentricity* of the earth's orbit were increased, period remaining the same, our winters would be *warmer*.

If the *tilt* of the earth's axis were increased, our winters would be *warmer*.

If the earth were *closer* to the sun, *annular* eclipses would be more frequent.

The multiple-choice type of test is also useful, i.e.:

The diameter of the sun exceeds that of the moon by (a) 50, (b) 100, (c) 200, (d) 400 times.

If the moon went around the earth in the opposite direction, solar eclipses would be (a) shorter, (b) longer, (c) more frequent, (d) less frequent.

Twilight is brief in the tropics because (a) the atmosphere is warm and moist, (b) the ecliptic is perpendicular to the horizon, (c) the sun's diurnal path is perpendicular to the horizon, (d) of the bulge of the earth at the equator.

A few illustrations of test items from an examination in Physics follow:

Directions: In this section you are given a description of a physical situation. Concerning this situation is a QUESTION to which you are to give an ANSWER.

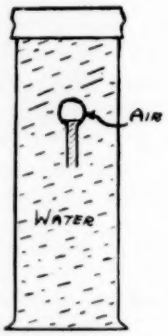
You may give your answer at once if you can, without referring to the STATEMENTS. Or you may use the STATEMENTS to assist you in finding the ANSWER. In either case you are to examine the STATEMENTS and classify them, using the letters A, B, and C, which are placed at the left of each statement. Encircle the letter A if the statement is false; encircle the letter B if the statement is true but is of no importance in finding the answer to the QUESTION; encircle the letter C if the statement is true and is useful in finding the ANSWER to the QUESTION.

Situation: A Cartesian diver is a small hollow glass body open at the bottom and containing sufficient air to make it slightly lighter than water so that it floats with very little of its volume projecting above the surface. It is placed in a vessel full of water which is closed above with an elastic membrane. A pressure is exerted downward on the membrane until the diver sinks.

Question: What happens to the air in the diver?

Answer: The air in the diver will be .....

Statements:



1. A B C Air pressure in an enclosed chamber varies directly as the volume if the temperature is constant.
2. A B C The pressure exerted on a fluid is transmitted undiminished to all parts of the fluid.
3. A B C The pressure times volume of the air in the diver remains constant.
4. A B C The buoyant force on a body is equal to the weight of the displaced volume of water.
5. A B C Reducing the size of a body by contraction increases its density.
6. A B C The density of the water is increased by the pressure on the membrane.
7. A B C The fluid pressure at the bottom of the vessel is greater than that at the top.

Modified True-False.

The acceleration acquired by a body in *falling* from a *height h* is equal to the *velocity* of *projection* necessary to send it up vertically a distance *k*.

A *point* on the *circumference* of a wheel rotating at a constant rate is moving with a constant velocity.

The sum of *two velocities*, both having a magnitude of 5 ft. per sec., may be any velocity between zero and 25 ft. per sec.

Multiple-Choice.

A baseball curves to the left or right because (1) the air pressure on one side of the ball is reduced, (2) gravity has a component sideways, (3) spin reduces the speed of the ball, (4) spin of the ball creates a centrifugal force.

A ship is moving north 20 mi./hr. The pennant flying at the top points exactly southeast. The wind, which is blowing 20 mi./hr., is blowing toward the (1) southeast, (2) south, (3) west, (4) east.

Curves are banked to (1) raise the center of gravity of car, (2) assist drainage of water, (3) keep cars from slipping off the road, (4) reduce force on wheels.

A few illustrations from Physiology are:

Directions: Select the most logical inference that can be drawn from the recorded facts.

After a frog is pithed, an injection of strychnine is made into the dorsal lymph sac. A few minutes later, the frog is touched on the leg and immediately goes into spasms, i.e., general muscular contraction. When it has gradually relaxed, it is touched again but this time on the skin over the abdomen. The same result is noted as when it was touched on the leg.

a. The higher centers are destroyed, therefore the frog has no control over its movements.
b. Strychnine acts like curare, poisoning the motor end plate.
c. Strychnine stimulates the muscles causing them to contract and remain contracted.
d. Strychnine causes the resistance of the synapse to be increased making it more difficult for the impulse to spread.
e. Strychnine causes a more general dissemination of the initial impulses.
f. The frog goes into spasms and contractions to protect itself.
g. Strychnine poisons the blood stream.
h. Strychnine stimulates the nerves and makes them capable of transmitting impulses better.

Modified True-False.

Cells lose all of their primitive endowments when *differentiation* takes place.

The *educability* of an individual is dependent upon the possibility of conditioning reflexes.

If the *spinal cord* of a strychninized *frog* is destroyed the muscular spasms continue.

Multiple-Choice.

The body is made up of many small cells rather than one large cell because: (a) many small cells make the body stronger, (b) different kinds of cells are necessary for different kinds of work, (c) many cells give the body a definite shape, (d) cells are limited in size by the sphere of nuclear action, (e) sex differentiation would be impossible.

The ability to bend over backwards is ordinarily limited by the: (a) transverse processes of the vertebrae, (b) costal elements of the vertebrae, (c) the bodies of the vertebrae, (d) cartilages of the spinal cord, (e) spines of the vertebrae.

The destruction of one of the occipital lobes of the brain would cause: (a) total blindness in one eye, (b) total blindness in both eyes, (c) partial blindness in one eye, (d) partial blindness in both eyes, (e) total blindness in one eye and partial blindness in the other eye.

The validity of a test is contingent upon the extent to which it arranges students correctly on the basis of their total accomplishment. The measure of the validity of a test item is based upon its differentiating power between superior and inferior students. Although types of test items may not in themselves necessarily have distinctive differentiating powers, it is proposed to point out the differences in achievement between two groups of students on tests of acquisition of information and tests of application of information to new situations and problems (Table I). The two groups are the upper and lower quarters of a class of 132 students in physics.

TABLE I

THE MEAN-PERCENTAGE ACHIEVEMENT OF THIRTY-THREE SUPERIOR AS COMPARED WITH THE MEAN-PERCENTAGE ACHIEVEMENT OF THIRTY-THREE INFERIOR STUDENTS IN VARIOUS PARTS OF A PHYSICS TEST

Ability Tested	*Type of Test Items*	*Mean Percentage Scores*		
		Upper Quarter	*Lower Quarter*	*Difference*
Acquisition of information	Multiple Choice	72	38	34
Acquisition of information	Completion	71	33	38
Acquisition of information	Modified true-false	65	33	32
Acquisition of information	Matching	62	32	30
Solving problems	Problem presented	64	12	52
Interpretation of new situations	Description of experiment	55	15	40
	All Items	66	30	36

It is observed that the greater differences between the two groups are found in the ability to solve problems and to interpret new situations.

Inference No.	*Upper Quarter*	*Middle Half*	*Lower Quarter*	*Total*
a.....	7.7	12.7	30.8	15.9
b.....	—	11.4	10.3	8.3
c.....	7.7	12.7	12.8	11.5
d.....	46.2	27.8	15.4	29.3
e.....	5.1	5.1	5.1	5.1
f.....	—	2.5	—	1.3
g.....	—	3.8	5.1	3.2
h.....	30.8	21.5	20.5	23.6
No answer	2.5	2.5	—	1.8

In a test situation where several choices are presented a valid item should have a clean-cut solution, and at the same time the alternate response should attract a substantial number of people, more especially the inferior people. The percentage distributions of the responses of the upper quarter, middle half and lower quarter of 150 students to the first test item listed under Physiology (p. 31) were as shown above.

The analysis of a test situation taken from an examination in Astronomy illustrates that not all the items are valid in that one (A-7) is answered correctly by a greater percentage of the inferior than of the superior students.

No. of Item	*Upper Quarter*	*Middle Half*	*Lower Quarter*
A			
1	40	42.9	40
2	20	23.8	10
3	80	66.7	60
4	70	57.1	40
5	80	66.7	30
6	60	4.8	40
7	10	9.5	20
8	40	38.1	30
9	40	47.6	40
B	60	42.9	50
C	70	47.6	40
D	60	52.4	50
E	20	4.8	10
F	50	23.8	0
G	50	14.3	0
H	10	4.8	0

Space does not permit description of such attempts as have been made toward measuring the ability to use the scientific method or the possession of the scientific attitude. As a reminder that the problem has been in no way exhausted but its solution only begun, no attempt at summary will be made other than to state that any instruction in science worthy of the name must be directed at more than the acquisition of facts. Abilities to use the acquired knowledge must be developed through a discipline which will result in facility in analysis, interpretation, and drawing conclusions. Measures must be developed by which we can discern the extent of the acquisition. Teachers of science have here a great responsibility and a real opportunity in hastening the development.

A NEW LAWS OF MOTION APPARATUS

By Harold K. Schilling and David Eickhoff
Union College, Lincoln, Nebraska

One of the most interesting, yet most difficult subjects for the beginning student of physics is that of the motion of projectiles. Students find it hard to believe that all freely falling bodies have the same acceleration regardless of their initial velocities. In spite of imposing logic and mathematical demonstration, they have, down in the very bottom of their souls, grave doubts about the instructor's claim that a monkey will certainly be hit if he lets go of the branch from which he has been hanging at the precise moment when a bullet, which has

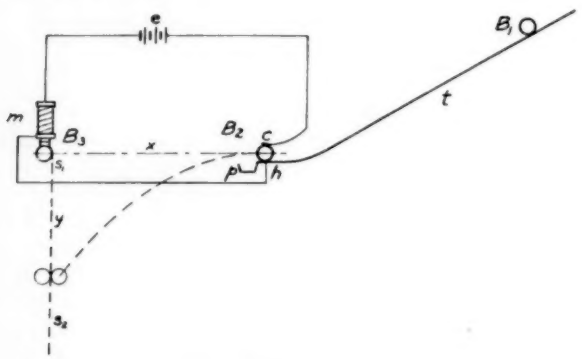


Fig. 1.

been aimed at him, leaves the muzzle of the gun—and at any angle of elevation of said gun. One cause for this skepticism has been the lack of suitable apparatus for the demonstration and study of such motion. It is, of course, well known that in the larger institutions facilities exist for the construction of suitable apparatus for demonstrating this principle in the lecture room. However, nothing simple, portable, and foolproof has been available for the student himself, or for the institution with modest resources.

We have used here, at Union College, a simple apparatus which is useful both in the lecture room and laboratory. With it any student can perform both qualitative and quantitative experiments which are quite convincing. The essentials of the apparatus are illustrated in Fig. 1.

The inclined track t (90 cm. long) consists of two parallel

metal tubes (a few mm. in diameter and about one cm. apart). At the bottom it is bent to make a short horizontal section *h*. Upon the track at *h* rests a steel ball B_2 held in place by clip *c*. At *m* is an electromagnet with cone-shaped pole piece. This is connected in series with a battery *e* and points *c* and *h*. When ball B_2 is in position at *h* the magnet circuit is closed and ball B_3 may be suspended from it. The magnet is so placed that the line of centers of the balls B_2B_3 is horizontal. When ball B_1 is allowed to roll down the track it will, during collision, transfer momentum to B_2 which will then be projected from the track with an initial velocity toward B_3. If the coefficient of restitution of the colliding balls is unity, the transfer of momentum as well as energy will be complete, and the two balls will simply

FIG. 2. The Cenco-Schilling Laws of Motion Apparatus.

exchange velocities. If the steel balls are properly selected, this condition is very nearly realized. When B_2 leaves the track, B_3 is released. B_1, with almost zero velocity, will be caught by clip *c* or will roll off the track into pocket *p*. Balls B_2 and B_3 will collide in mid-air.

One very great advantage of this apparatus is its great flexibility which permits all important factors to be varied at will, as shown in Fig. 2. The educational value of the demonstration is thus enhanced. The initial velocity of ball B_2 can be varied by releasing ball B_1 from different points along the inclined plane. Students are quite surprised (though perhaps they should not be) to discover that "it works" for all speeds. Magnet *m* is mounted on a bar (rigidly attached to the track as an integral part of the apparatus) in such a manner that it can be moved

horizontally over a range of 50 cm. thus varying the distance B_2B_3 at will. The student is surprised again that it "really works" for all such distances. Finally, the whole apparatus can easily be tilted up or down in the plane B_2B_3 so as to give the initial velocity of B_2 an upward or downward component. The student soon discovers that after all, the instructor may be right about the monkey, and that as long as the initial velocity is directed toward B_3, and B_2 and B_3 are released simultaneously one can do nothing to prevent the collision (though of course occasional misses do occur because of poor electrical contacts, etc.). The original model of the apparatus was constructed by a student in the laboratory and was rather crude.[1] Yet, with it we have actually scored hits ninety-five times out of a hundred tries for many different distances and angles of elevation.

The great value of the apparatus, however, lies in the possibilities it presents for sound fundamental quantitative experimentation. In the first place, as every teacher will recognize, all three of Newton's Laws of Motion are illustrated. Then, thinking of more particularized laws, one meets here the laws of motion along inclines, motion of freely falling bodies, motion of projectiles, etc. For the study of these in the elementary laboratory we have found the following simple theory very useful for quantitative work. It leads to a very simple, but very illuminating and suggestive equation which can easily be checked with the apparatus.

Let s be the distance ball B_1 rolls down the plane, x the horizontal distance ball B_2 moves before the collision, y the distance B_3 and B_2 drop before they collide. The velocity of B_1 at the foot of the plane is[2]

$$v_1 = \sqrt{2as} \qquad \text{Eq. 1}$$

where a is the acceleration along the plane. Then the initial velocity of B_2 will be

$$v_2 = K\sqrt{2as} \qquad \text{Eq. 2}$$

Hence the horizontal distance x will be given by

$$x = v_2 t = K\sqrt{2as}\ t \qquad \text{Eq. 3}$$

where t is time. The vertical distance of drop is, of course,

$$y = \tfrac{1}{2}gt^2 \qquad \text{Eq. 4}$$

[1] On the basis of our original design, The Central Scientific Company of Chicago has developed and is offering for sale a very fine portable model of the apparatus known as the Cenco-Schilling Laws of Motion Apparatus.

[2] There will be a slight error due to the fact that the track is curved at the bottom. If s is not made shorter than 20 cm this error is negligible in practice.

Eliminating t from Eqs. 3 and 4,

$$y=\frac{g}{4K^2a}\frac{x^2}{s}=C\frac{x^2}{s} \qquad \text{Eq. 5}$$

where C equals $g/4K_2a$, and may be regarded as a constant of the apparatus. There appears therefore the rather surprising, simple hyperbolic relation that for a given value of x the distance y is inversely proportional to s. This can easily be checked by the student. In our laboratory we attach a meter stick by means of standard meter stick clamps to a 19 mm. rod, supported on a tripod stand. Scotch tape is used to attach a strip of red sensitized paper to the meter stick. This assembly is placed immediately under the magnet so that the strip coincides with line S_1S_2 in Fig. 1 and so that the zero of the meter stick and strip coincides with the line of centers B_2B_3. When B_1 is released at different distances s along the track, B_2 will strike the sensitized paper at various distances y. When a ball strikes such paper, the point is marked by a small dark red spot very much as is the case in the more familiar spark records. The points of contact and collision[3] are thus automatically recorded. A student can obtain several such records for different x distances in a very short time and can study and measure them at his leisure. In this way a fairly large class can perform this experiment during one laboratory period, even though only one apparatus is available.

The last equation gives also the well-known parabolic relation for projectiles with horizontal initial velocity; that is, for a given value of s, y is directly proportional to the square of x. It will be apparent at once how this can be checked. The strip and support assembly is placed successively at points having various x distances, ball B_1 being released at the same point on the incline. On the same strip therefore, will be the record of impacts at different distances x, the initial velocity being constant. This is virtually a record of the flight of a projectile with a horizontal initial velocity. Several records can then be obtained for different initial velocities, i.e. for different values of s. This experiment will take slightly more time than the previous one. In both cases smooth curves fitting Eq. 5 can easily be obtained which even elementary students will find very instructive.

[3] Ball B_3 is dispensed with in this experiment. This is legitimate because the student has already seen in the introductory qualitative demonstration that balls B_2 and B_3 arrive simultaneously at the same point along S_1S_2.

Aside from these more fundamental and obvious experiments, both students and teacher may devise other experiments which will be eminently suitable as laboratory projects for those wishing to go beyond the laboratory manual and instruction sheet.

Finally, we have found this piece to be a valuable interest stimulant. We have mounted one apparatus permanently on a small wall shelf in the laboratory, where students and visitors may "play" with it at any time. It never fails to provoke interesting and worthwhile discussion.

AN AID TO THE STUDY OF OPTICAL PHENOMENA

By DR. A. J. GINSBERG

Light and the study of optics, while a subject of major interest to the philosopher and physicist for hundreds of years, remains a mystery to the average man. Thus when such a term as "optical bench" is mentioned, laymen greet it with expressions of polite curiosity, or simply raise their eyebrows. Indeed, it is surprising how many well educated persons are almost completely ignorant regarding a branch of science that concerns almost every phase of modern life.

Investigation has shown that this lack of interest is due primarily to the inadequate attention given courses in optics by the average high school and college. Undoubtedly instructors have been handicapped by the high cost of good optical equipment, and being unable to give interesting and attention holding demonstrations, have been obliged to rely on the theoretical exposition of literature and the lecture room. Only well endowed institutions with ample funds for laboratory equipment can afford to provide adequate optical apparatus of the types heretofore available for individual instruction and experimentation.

Heretofore, such an important adjunct to the physics laboratory as the optical bench has been too costly when accurate enough for research work; or if cheap enough for individual experimentation, has been too inaccurate and limited in application to be used for research work.

There have recently appeared advance notices of a new optical bench which represents a revolutionary improvement in design and manufacture, permitting it with its accessories to be offered at prices easily within the reach of the average industrial laboratory, high school, or college. With it almost every conceivable experiment in optics can be performed, either by individuals for experiments in reflection, refraction, diffraction, polarization, telescopy, microscopy, photography, spectroscopy, etc.

The usefulness of the bench can be further extended into the fields of photo-electric and thermo-dynamic phenomena by the addition of suitable equipment. Such devices are already designed and under construction and more items will be added to the already extensive list as the demand increases.

It is pointed out by the manufacturer that a laboratory or individual interested in optical research may make a modest beginning by purchasing the fundamental equipment required for elementary experiments. The more elaborate accessories may be added from time to time with assurance that each unit will be found perfectly adapted to the whole set.

THE TESTING MOVEMENT IN HIGH SCHOOL BIOLOGY

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I

In the past, educators have deplored the fact that many of the published tests in the field of high school science are of little worth, either for routine testing in the classroom or for controlled experimentation. In a compilation of educational tests, written at a time when interest in standardized examinations was at its peak, it is stated:

> It is recognized that some of the tests are almost, if not wholly worthless. Nevertheless, they have been given equal rank with those of distinctive merit in that the alphabetical method of listing has been used, and no statement has been made as to the quality of the test.[1]

In much the same fashion, other books and articles devoted to tests have done little more than list them in alphabetical order; scarcely any effort being made to sift out the poor ones.

In one of his essays, Matthew Arnold points out that "the critical power is of lower rank than the creative." Nevertheless, provided one criticises in a helpful and constructive spirit, there can be no justifiable objection to pointing out where one's experiences have been at variance with those of another. This article is based upon an analysis of tests in the field of high school science,[2] upon a correspondence with test authors over a period of years, and upon the writer's experience as a teacher of biology during which time he administered many standardized tests to his classes.

II

As is generally recognized, the testing movement originated at the primary school level. Under the lead of Thorndike[3] and his students, tests were constructed for the elementary school from 1904 onwards. It was not until 1916 that the first achievement test in high school science was published by Daniel Starch, then teaching at the University of Wisconsin.[4] While

[1] Bureau of Cooperative Research, *First Revision of Bibliography of Educational Measurements*, Indiana University, Bloomington, Ind., May, 1925, p. 3.

[2] Cf. the writer's master's thesis. Cornell University Library, *A Critical Examination of Tests in High School Science*, 1931.

[3] Thorndike, E. L., *An Introduction to the Theory of Mental and Social Measurements*, Teachers College, Columbia University, New York, 1904. (Revised in 1913.)

[4] Starch, D., *Educational Measurements*, Macmillan and Company, New York, 1916.

this pioneer test was concerned with physics, it had a great influence upon the construction of succeeding tests of biology. This is particularly true with regard to selection of test items.

In constructing his test, Starch made a careful survey of five leading physics textbooks; selecting the most important principles to be found in each. He discovered that there were 170 principles common to four of these texts and 102 common to all five. These 102 principles were then incorporated into 75 questions of the simple completion type which were administered to a single class taking high school physics. On the basis of the small number of individuals taking this test, tentative norms were established. These norms were never revised since the test was not used on any extensive scale.

An objection which one might raise to this, and to many of the tests which have followed in biology, is that their materials are entirely, or in large part, derived from textbooks. While it cannot be denied that the textbook furnishes a valid and accessible source for deriving test items, its sole use tends, indirectly it is true, to make the "book-work" element in science unduly prominent. Memoriter knowledge of the text becomes of paramount importance in the determination of student success.

The first achievement test in biology was published in 1918 by N. M. Grier,[5] then teaching at the Central High School in St. Louis. It is interesting to note that the construction of this test was undertaken at the suggestion of Dr. E. L. Thorndike of Teachers College who wanted to ascertain the extent of information students had acquired in the elementary school as a means of cutting down unnecessary duplication at the secondary level.

Grier constructed a series of three sub-tests; one in physiology, one in botany and one in zoology. This was in accordance with current teaching practices which presented, not a unit course of general biology, but the three divisions of animal, plant, and human biology. The last division was known as physiology. Each sub-test consisted of 100 words which the students were asked to define. The manner in which these terms were secured was consistent with the purpose of this test. In physiology, they were obtained from an analysis of readers and spellers used by the students in the elementary school. They

[5] Grier, N. M., *The Range of Information Test in Biology*, Journal of Educational Psychology, I–Physiology, II–Zoology, 9: 210–16, 388–92, April, September, 1918. III–Botany, 10: 509–16, December, 1919.

were supplemented by others derived from a number of articles dealing with pure food and health which had appeared in daily newspapers and monthly magazines. The same sources were used in constructing the other two sub-tests save that the supplementary terms were obtained from Boy Scout and Camp Fire Girl publications.

Students taking the test were given the following instructions:

1. Place a D before the terms you can define as exactly as words are ordinarily defined in the dictionary.
2. Place an E before the terms you can explain to one not familiar with their meaning.
3. Place an F before the terms with which you are roughly familiar.
4. Place an N before the terms which are new to you.
5. At the bottom write out the definitions of the first five words you marked D, and the first five you marked E.

A major difficulty which arises in using this test is that it is difficult to answer or score in any objective fashion. When the writer presented this test to the students in four biology classes, they were quite confused with regard to the difference between those words they could explain to another (E), and those they knew roughly (F).

A frequent criticism of this type of test is that, deliberately or not, it places too much emphasis upon dictionary definitions. While it cannot be denied that the ability to define accurately is a most desirable accomplishment, its possession should not be unduly rewarded. Worthwhile measurement in high school science is accomplished to the extent that tests are conditioned by as many of the accepted aims of science teaching as possible. If, among our major objectives, we include the ability to solve original problems, the development of scientific attitudes and interests, skilful laboratory technique, as well as the ability to define accurately; the next step is to endeavor to devise tests which will measure all of these. Future progress in testing must be sought not so much in the over-refinement of our statistical techniques but in devising tests based upon an increasing number of the aims and objectives of science. In this connection, it might prove valuable for each test-maker to indicate which objectives have been measured and which ones omitted from his test.

The Ruch-Cossman *Biology Test*,[6] published in 1924, was

[6] Ruch, G. M., and Cossman, L. H., *Ruch-Cossman Biology Test*, World Book Company, Yonkers-on-Hudson, New York, 1924.

Ruch, G. M., and Cossman, L. H., *Standardized Content in High School Biology*, Journal of Educational Psychology, 15: 285–96, May, 1924.

based upon a tentative test which L. H. Cossman had constructed at the University of Oregon in 1918. Cossman's test was similar to that of Grier in that the examinees were asked to define important biological concepts. They were also asked to sketch a typical insect, a typical flower, etc. In securing materials for this preliminary form, Cossman was the first to make extensive use of teacher's final examinations. A letter was sent to all State Superintendents of Public Instruction asking that they list the names of those teachers who were doing exceptional work in biology. He received replies from 23 states giving a total of 126 outstanding teachers. Each of these was requested to send duplicate copies of all final examination questions used during the current and previous years. Slightly over 2000 questions were received. After being analyzed for frequency, condensed and classified into 300 test items, these questions were submitted to 100 teachers and authorities on the teaching of biology for rating. As a result, the number was finally reduced to the 226 items which make up the Ruch-Cossman test.

Although this test is among the earliest in the field, when judged from the standpoint of scientific accuracy, it is superior to any of the others. In fact, the Ruch-Cossman test was found to be the only one entirely free from scientific errors in a recent study made by the writer.[7]

Cooprider's *Information Exercises in Biology* had its inception in 1920 when the author, then teaching in a high school at Evansville, Indiana, began a survey of the vocabularies to be found in textbooks of biology.[8] A preliminary test form was constructed and given to approximately 350 students as a means of cutting out faulty items. A second survey was made in 1922, bringing the total to 9 textbooks so treated. The test was finally published in 1924.

This test furnishes a good illustration of how one can make statistics highly reliable for something which is not sound in itself ($r = .92$), since it contains glaring errors which lead one to ask whether it is not more important to secure scientifically accurate test items than to spend much time in securing elaborate statistics. Thus, in the recent study made by the writer, it was found that 15% of the items appearing in Cooprider's test

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[7] Diamond, L. N., *Testing the Test-Makers*, School Science and Mathematics, May, 1932, Vol. XXXII, No. 5, pp. 490–502.

[8] Cooprider, J. L., *Information Exercises in Biology*, Public School Publishing Company, Bloomington, Ill., 1924.

require extensive revision from the standpoint of scientific accuracy.[9]

The *Michigan Botany Test,* published in 1925, is the only standardized test in this subject.[10] It was prepared by O. W. Laidlaw, a graduate student at the University of Michigan, under the direction of Dr. Clifford Woody. It was based upon subject matter common to five widely used textbooks of botany and, before publication, was submitted to many teachers of botany and agriculture for their opinion concerning its worthwhileness. While the test has a high reliability and was constructed in accordance with the best-known procedures, it has been supplanted by more inclusive tests. As Dr. Woody writes:

> I am of the opinion in 1933 that the Michigan Botany Test developed in 1922 has practically outlived its usefulness. It was prepared at a time when the testing movement was young and when there were so many demands for it in the high schools of Michigan that Mr. Laidlaw and myself thought it might be wise to have it printed. Since that time, however, much more extensive—and probably much better tests—have been prepared.

The *Catholic High School Test in Biology* was published in 1926 by E. B. Jordan and T. G. Foran of the Catholic University of America.[11] It was first constructed as three separate tests of botany, zoology and human physiology. However, this organization was later abandoned in favor of a single test of general biology. The test items were secured from a number of texts used by Catholic high schools affiliated with the University and from a study of the technical vocabularies of biology made by Pressey. The test is well constructed, scientifically accurate and appears to be suitable for use in any high school. Incidentally, it bears a strong resemblance to Ruch and Stoddard's test, particularly with respect to the organization of materials.

The following year, O. W. Richards, then teaching at the University of Oregon, published the *Richards Biology Test.*[12] the test items were derived from six widely-used textbooks of biology according to the amount of space devoted to each topic. A preliminary test form was submitted to a number of experienced

[9] Cooprider, J. L., *Information Exercises in Biology,* p. 501.

[10] Laidlaw, O. W., and Woody, C., *Michigan Botany Test,* Public School Publishing Company, Bloomington, Ill., 1925.

[11] Jordan, E. B., and Foran, T. G., *Catholic High School Test in Biology,* Catholic University Press, Washington, D.C., 1926.

[12] Richards, O. W., *Richards Biology Test,* Stoetling Company, Chicago, Ill., 1927.

Richards, O. W., *Test Construction in Less Standardized Subjects Illustrated by the Richards Biology Test,* School Science and Mathematics, 28: 22–27, January 1927.

teachers before the final form was published. A point worthy of our attention is the fact that the norms for his test are purely tentative. With reference to this, he says:

> It seems fruitless to attempt to compare the scores of one school with any other unless the courses are known to be the same. Therefore the establishing of norms must be done for a particular course over a period of years by the teachers of that course. . . .
>
> Are norms justified in a subject whose content is as broad as that of biology and whose courses and methods must be especially adapted to the needs of the community that that course serves, whether it be for the farm, the small town, . . . or for the children of the tenement districts of large cities which may be inland or on the seacoast.[13]

While there is much to be said for this point of view, it may be said that the use of norms in standardized tests arose as a means of combatting the general lack of agreement concerning the standards of high school accomplishment. A chaotic lack of uniformity existed between the curricula of neighboring cities, which produced great hardship when students transferred from one school system to another.[14] Insofar as the testing movement has helped alleviate this condition—indirectly, it is true, since measurement is not a means of instruction but a method of testing the results of instruction—it has justified itself. Nevertheless, to the extent that standardized tests with nation-wide norms infringe upon the individuality of a curriculum designed for the needs of a given community, they defeat the larger purposes of education. However, it should be borne in mind that a standardized test is designed to cover only the "high spots"; the essentials which must be included in any valid course of high school science. If any school system choses to teach *only* these essentials, at the expense of interpreting the local environment, surely it is not the fault of the standardized tests.

The above discussion furnishes an appropriate introduction to the *Virginia Biology Test* since it was especially designed for use in the state of Virginia.[15] It was written in 1928 by T. S. King as a master's thesis at the University of Virginia. It was based, in large part, upon the study of teacher's examinations made by Ruch and Stoddard.[16] The items obtained from this source were checked against subject matter appearing in Pea-

[13] Op. cit.

[14] Finley C. W. *Biology in Secondary Schools and the Training of Biology Teachers*, Teachers College Columbia University, Contributions to Education No. 199, New York, 1926.

[15] King F. S. *Virginia Biology Test*, University of Virginia. University, Va., Bureau of Tests and Measurement 1928.

[16] Vide: p. 41, note 6.

body and Hunt's textbook of biology,[17] and against the Virginia State Course of Study in Biology. Originally, there were over 1500 items which, after trial and criticism in a number of high schools in that state, were reduced to 386. This test is longer than any of its predecessors, a fact which would tend to increase its reliability. It appears to be carefully constructed save for some errors of fact. Thus, the statement that poison ivy has three leaves is given credit as being correct.[18]

In 1929, J. G. Blaisdell, teaching in a high school at Yonkers, New York, published his *Instructional Tests in Biology*.[19] It is one of the few tests written by an individual actually teaching in a high school rather than in a college or teacher-training institution. This test is by far the longest in the subject, consisting of some 1,250 items divided into 25 sub-tests. Concerning its derivation, Blaisdell writes:

> 1.The subjects for the several tests were determined from the chapter and section headings appearing in the most widely used biology textbooks and in selected state and city courses of study. The questions selected for each test were checked against the textbooks in order to make sure that each question was covered in most, if not all, of these books.
>
> 2. The Instructional Tests were tried out in schools in more than ten cities in various parts of the United States. On the basis of the data obtained, questions were eliminated or modified.

Each sub-test covers a definite unit of instruction and is intended to be given after the unit has been covered in class. Due to its great length and the amount of subject matter covered, this test is adapted for the specific diagnosis of student weakness and the direction of remedial work. It bears evidence of careful construction and has proven of great value in the testing programs of many high schools. The suggestion is made that a series of pretests for each unit might also prove of value in accordance with the unit-problem organization of Dr. Morrison of the University of Chicago.

A *Test of General Biology* was also published in 1929 by M. E. Oakes and S. R. Powers of Teachers College, Columbia University.[20] It has attracted favorable attention because of the variety of sources used in its derivation. Among these are:

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[17] Peabody, J. M., and Hunt, A. E., *Biology and Human Welfare*, Macmillan and Company, New York, 1924.

[18] Op. cit. Form A, Test 2, No. 16.

[19] Blaisdell, J. G., *Instructional Tests in Biology*, World Book Company, Yonkers-on-Hudson, New York, 1929.

[20] Oakes, M. E. and Powers, S. R., *A Test of General Biology*, Teachers College, Columbia University, Bureau Tests and Measurements, New York, 1929.

1. An examination of the New York State Regents Examinations in elementary and advanced biology over a period of years.
2. The study of teacher's examinations made by Ruch and Cossman.[21]
3. An analysis of the content of high school textbooks of biology.[22]
4. A series of health tests used at the secondary school level.[23]
5. A study of biological literature appearing in the public press.[24]
6. A study of the larger objectives of science.[25]

At present, an organization of educators known as the Co-operative Test Service is developing a series of tests in various subjects for the American Council on Education.[26] Specifically, their purpose is to turn out a continuous supply, year after year, of comparable and valid achievement tests of the subjects taught in the late high school and early college years. This continuous production of carefully standardized tests in multiple forms, one form each year, was undertaken for purposes of educational research and reform since:

> . . . there are for most subjects only one or two or three tests and for some subjects none. Moreover, most of the tests, such as there are, exist in only two equivalent forms, and when these two forms have been used two or three times in the same school, it is no longer safe to use them there; either the questions "get out" or unfair coaching may occur. And finally, many of the existing tests exhibit certain deficiencies which have resulted naturally from their being constructed by individual authors without sufficient funds and services at their disposal to effect complete standardization; hence inadequate norms and lack of comparability in some of the measures.
>
> It is to overcome this . . . that the American Council Committee has set up in the Co-operative Test Service a continuing factory for the manufacture, year in and year out, of this particular kind of scientific measuring tool, so essential to the progress . . . of educational research and experiment.

The initial test in biology was constructed for the Service by S. R. Powers and F. L. Fitzpatrick in 1932.[27] It is suitable for measuring achievement in advanced biology at the high school level or for general biology at the college level. It appears to be carefully constructed both from the standpoint of scientific and

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[21] Vide: p. 41, note 6.

[22] Hackett, G. L., *An Analysis of High School Textbooks in Biology*, Unpublished master's thesis, University of Chicago, 1924.

[23] Laton, A. D., *The Psychology of Learning Applied to Health Education*, Teachers College, Contributions to Education. No. 344, New York, 1929.

[24] Craig, G. S., *Certain Techniques Used in Developing a Course of Study in Science for the Elementary School*, Teachers College, Columbia University, Contributions to Education No. 276, N. Y. 1927.

[25] Finley, C. W., and Caldwell, O. W., *Biology in the Public Press*, Lincoln School of Teachers College, Columbia University, N. Y., 1923.

[26] McConn, M., *The Co-operative Test Service*, The Journal of Higher Education, May, 1931, pp. 225–232.

[27] Powers, S. R., and Fitzpatrick, F. L., *Biology Test*, Co-operative Test Service, New York, 1932.

statistical accuracy. As stated above, it will be succeeded by comparable forms each year. The writer suggests that the same be done for elementary biology since only in this manner can a thorough-going program of educational guidance and research be undertaken; a program which would be difficult, if not impossible to follow using unrelated tests existing in only one or two comparable forms.

In 1930, T. R. Stemen and W. S. Meyers, both teachers of biology in Oklahoma City, constructed an achievement test in biology.[28] It is somewhat smaller than that of Blaisdell, consisting of six sub-tests, each of which includes 100 test items. The test is not an outstanding one, but it does cover the field of general biology in an adequate fashion.

One of the latest tests was constructed in 1930 by J. M. Presson as a doctor's dissertation at the University of Pennsylvania.[29] In securing the materials for his test, Presson obtained a list of topics from the 7 most widely used textbooks of biology; from an extensive series of tests sent in from all parts of the country by outstanding teachers; from questions of the College Entrance Examination Board; and from examinations of the Board of Regents of New York State. Recognizing the purposes for which it was prepared, this test is among the best in the field of high school science.

Finally, we come to a group of miscellaneous measures which are somewhat off the beaten track of testing. In 1924, Pressey published a series of word lists in many high school subjects.[30] Her purpose was to ascertain the technical terms appearing in science textbooks and to secure an approximation of their relative importance as tools in the understanding of important concepts. She made a systematic examination of the most important texts in each subject, selecting a tentative list of words which students might have difficulty in understanding but which were requisite to progress. These were checked against lists of terms which teachers, taking work at a summer session of Ohio State University, thought essential. In this manner, the relative importance of each word was gauged.

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[28] Stemen, T. R., and Meyers, W. S., *Comprehensive Test in Biology*, Harlow Publishing Company, Oklahoma City, Okla., 1930.

[29] Presson, J. M., *Presson Biology Tests*, World Book Company, Yonkers-on-Hudson, New York, 1930.

Presson, J. M., *Achievement Tests in Biology*, Doctor's Thesis, University of Pennsylvania, Philadelphia, 1930.

[30] Pressey, L. C., *The Technical Vocabularies of the Public School Subjects*, Section 7, Biology, Public School Publishing Company, Bloomington, Ill., 1924.

In biology, the student is instructed to go through the list carefully, checking the words he does not know and looking up their meaning later. Strictly speaking, these lists of words are not tests, but they may be effectively used, with the proviso that they be brought up to date, for diagnostic and remedial work. As Pressey states:

III. Statistics of Biology Tests

Test	*Date*	*Total Quest.*	*Types Quest.*[1]	*Sources Utilized*[2]	*Objectives Measured*[3]
1. Grier	1918	300	6	1–5	4
2. Ruch-Cossman	1924	224	1–2–4–7	2–6	1
3. Cooprider	1924	94	1–3–4–8	1–6	1
4. Pressey	1924	1390	6	1–6	4
5. Laidlaw-Woody	1925	70	1–2–5	1–6	1
6. Jordan-Foran	1926	218	1–2–4–7	1–6	1
7. Richards	1927	100	1	1–6	1
8. King	1928	386	1–2–3–4–7	1–2–3–6	1
9. Blaisdell	1929	1250	1–2–3–4–8	1–6	1
10. Oakes-Powers	1929	200	1–2–3–8–7	1–2–4–5–7	1
11. Van Wagenen	1929	126	5	1–6	3
12. Stemen-Meyers	1930	600	1–2–3–4–7	1–6–7	1
13. Presson	1930	460	1–2–4–7	1–2–4–6	1
14. Powers-Fitzpatrick	1932	90	1–2	1–6	1

[1] 1—multiple-choice
2—selection or matching
3—true-false
4—completion
5—simple question
6—definition of terms
7—labelling diagrams
8—miscellaneous

[2] 1—textbooks.
2—teacher's final examination questions.
3—state and city courses of study.
4—Board of Regents and College Entrance Examination Board questions.
5—newspapers and magazines.
6—rating by teachers and authorities in the field of science teaching.
7—miscellaneous.

[3] 1—Acquaintance with biological facts, phenomena and principles.
2—Biological attitudes and interests. (Appreciation of rôle of biology as a tool in understanding and solving the problems presented by the environment.)
3—Reading ability in biology.
4—Mastery of vocabulary of biology.
5—Ability to solve *original* problems, using biological principles.
6—Knowledge of laboratory procedures and techniques, involving the use of actual apparatus.

The vocabulary factor has not received the attention it deserves as a factor conditioning the efficiency of reading and studying. Much of the difficulty which students have in studying their textbook is due to lack of knowledge of the important technical words in a subject rather than to lack of any general silent reading ability.

In 1929, M. J. Van Wagenen of the University of Minnesota published his reading scales in biology.[31] These were designed to measure the reading ability of the student, consisting of 15 carefully chosen biological selections. Below each is a number of statements, concerning which the following instructions are given:

Read the first paragraph through carefully. Then read the first statement below the paragraph. If the idea it expresses is stated in the paragraph, even though in different words, place a check mark in front of it. If the idea in the statement can be derived or inferred from the ideas in the paragraph, also place a check mark in front of the statement. In all other cases, place a cross before the statement.

So far as the writer knows, this is the only test in the field which endeavors to measure the ability to read, interpret and to understand. It is of especial value in remedial work, when used in conjunction with Pressey's word lists, since it tells the teacher why a student cannot keep up with his fellows in the acquisition of scientific vocabulary and the mastery of reading ability.

[31] Van Wagenen, M. J., *Van Wagenen Reading Scales in Biology*, Public School Publishing Company, Bloomington, Ill., 1929.

MORE CHILDREN—LESS MONEY

728,000 more children were enrolled in high school in 1932 than in 1930; 115,000 fewer children were enrolled in elementary school in 1932 than in 1930 (the first decrease in the history of the country). Net gain: 613,000 pupils. This is more than the entire population of Montana. It is more than the combined populations of Atlanta, Des Moines, and Salt Lake City. It is more than were enrolled in all our public high schools in 1900. Today 93 of every 100 city children enroll in high school; 55 of every 100 rural children do likewise.

Abolition of child labor in industry by the NRA will, it is estimated, put another 100,000 children on the high school doorstep. In one small Southern town it added 137 pupils.

Any industry faced with rapid increase in business would expect an increase in total operating costs. But schools, forced to carry an increased burden, are required to carry on with less funds.

A CRITICISM OF THE TREATMENT OF THE REGULAR POLYGON CONSTRUCTIONS IN CERTAIN WELL-KNOWN GEOMETRY TEXTS

By Dewey C. Duncan
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In glancing through a recently published and widely adopted text in Plane Geometry the writer's attention was drawn to a discussion relating to the possibility of constructing the regular polygons by processes of elementary geometry. This discussion, while purporting to give the most recent information, is somewhat misleading and conveys inpressions decidedly contrary to fact. The exposition is here reproduced in full.

THE NUMBER OF INSCRIBED REGULAR POLYGONS

"It has been shown how to construct [geometrically, i.e , by ruler and compasses alone] regular inscribed polygons of 3, [4], 5, 6, 10, and 15 sides. It has also been shown that by bisecting arcs regular polygons having 2, 4, 8, · · · times as many sides as the preceding can be inscribed. These facts can be compactly stated as follows: a circle can be divided [geometrically] into n equal parts if $n=2^m$, 3, 5, or the product of any two or three of these numbers. Here 2^m takes care of the doubling of the number of sides by the bisection of arcs. All this was known to the later Greek geometers. Whether there were other regular inscribed [geometrically inscriptible] polygons than these was unknown until Gauss (1777–1855), when only nineteen years old, showed that a circle could be divided into 17 equal parts. Later he enlarged this series of numbers by showing that the division of the circle into n equal parts is *possible* [geometrically] for every prime number $n=2^{2^m}+1$ but *impossible* for other prime numbers and their powers. Assigning values to m, we obtain corresponding values of n as follows:

$m=0$	1	2	3	4
$n=3$	5	17	257	65537

in which all the values of n are prime. Hence inscribed regular polygons with these five values are possible [by ruler and compasses alone]. This means that regular polygons of 7, 11, 13, 19, 23, · · · equal parts cannot be inscribed [geometrically] in a circle. From 3 to 257 inclusive there are 56 prime numbers and it is entirely unexpected to find that for only the four of these

which are given in the table is a regular inscribed polygon possible.

"To find other values of n and prove them prime is a problem in the theory of numbers. Very recently it has been shown that if $m \leqq 100$ there are 24 values of n, that if $m \leqq 1000$ there are 52 values of n, and that if $m \leqq 100{,}000$ there are 206 values of n. Thus the five values of n in the table have been extended to 206. Undoubtedly for values of m greater than 1000 the formula of Gauss gives other prime numbers. How many there are beyond the 206 already known to exist is, however, an unsolved problem."

The first paragraph here quoted, except for the *possible omissions* indicated in square brackets summarizes the situation in a singularly clear and accurate manner. Unfortunately this superior statement of the case is spoiled by the concluding paragraph which appears to be a faulty adaptation of a summary such as one finds in Klein's *Famous Problems of Elementary Geometry*, Second edition, revised and enlarged with notes by R. C. Archibald, (Stechert, N. Y. 1930). Incidentally, this valuable book, now listed at one dollar and fifty cents, should be in the library of every progressive teacher of mathematics. On page 81 of this work we read

". . . The number of such [inscriptible] polygons is small in comparison with the number of regular polygons which can not be constructed with the means employed [ruler and compasses]. As Dickson has pointed out [*Bull. N. Y. Math. Soc.*, Feb., 1894, v. 3, p. 123] the number of P's up to 100 is 24; up to 300 is 37 (all noted by Gauss); up to 1000 is 52; up to 1000000 only 206."

An examination of the treatment of this topic and the discussions thereto appended in the following well-known texts on High School Geometry seems to indicate that a recapitulation of the facts on this subject gleaned from the historical sources should not be entirely inappropriate or unwelcome.

Plane Geometry, Solomon-Wright (Scribner) 1929.
Plane Geometry, Good-Chipman (Lippincott) 1930.
Plane Geometry, Hassler (Lyons-Carnahan) 1930.
Plane Geometry, Palmer-Farnum-Taylor (Scott-Foresman) 1924.
Plane Geometry, Strader-Rhoads (Winston) 1927.
Plane Geometry, Nyberg (American Book Co.) 1933.
Plane Geometry, McCormack (Appleton) 1928.
Plane Geometry, Haertter (Century) 1928.
Plane Geometry, Avery (Allyn-Bacon) 1931.
Plane Geometry, Sykes-Comstock (Rand-McNally) 1933.

Plane Geometry, Morgan-Foberg-Breckenridge (H-Mifflin) 1933.
Plane Geometry, Cowley (Silver-Burdett) 1932.
Plane Geometry, Young-Schwartz (Holt) 1923.
Plane Geometry, Welchons-Krickenberger (Ginn) 1933.
Plane Geometry and its Uses, Merick-Newell-Harper (R-Peterson) '29.
Modern Plane Geometry, Wells-Hart (Heath) 1926.
Senior Mathematics, Book II, Breslich (U. of Chgo. Press) 1930.
Beginners' Geometry, Smith (Macmillan) 1932.
Modern Plane Geometry, Clark-Otis (World Book Co.) 1926.
New Plane Geometry, Hawkes-Luby-Touton (Ginn) 1933.
Essentials of Plane Geometry, Smith (Ginn) 1923.
Plane and Solid Geometry, Stone-Mills (Sanborn) 1916.
Plane and Solid Geometry, Ford-Ammerman (Macmillan) 1923.

Five of these texts make no reference to the possibility of constructing regular polygons besides those immediately obtainable from the square and hexagon, the others include, either in the text or in the appendix, the standard constructions of the decagon and related polygons, the pentagon and pentadecagon, and those immediately obtainable from them by doubling the number of sides. Of course these constructions may well be omitted in view of the Report of the National Committee on Mathematical Requirements, entitled *The Reorganization of Mathematics in Secondary Education*, 1923. One of these five texts treating only the simplest cases closes the discussion with this brief note:

Regular polygons in general. We have seen that as soon as the side of any inscribed regular polygon is known, the sides of inscribed and circumscribed regular polygons of double the number of sides may be found. Thus beginning with the square, the sides of regular polygons of 4, 8, 16, 32, $\cdots$, 2^n sides may be found; beginning with the regular hexagon, the sides of regular polygons of 3, 6, 12, 24, $\cdots$, $3 \cdot 2^n$ sides may be found.

In another we read:

In preceding problems and exercises you have learned how to construct regular polygons of 3, 6, 12, 24, 48, $\cdots$, sides and of 4, 8, 16, 32, $\cdots$, sides. It is also possible by simple methods to construct regular polygons of 5, 10, 20, 40, $\cdots$, sides, and 15, 30, 60, 120, $\cdots$, sides. The geometers of Euclid's time could perform these constructions but knew no methods of constructing regular polygons not in one of the four regular series of numbers given above. For 2000 years no other types of polygons were added to the list. In the early part of the nineteenth century Gauss, a German mathematician, showed that a polygon of 17 sides could be inscribed in a circle. In general *he proved that a regular polygon can be inscribed in a circle if the number of sides N is given by the formula* $N = 2^{2^n} + 1$. If $n = 0$, $N = 3$; if $n = 1$, $N = 5$; if $n = 2$, $N = 17$; if $n = 3$, $N = 257$; etc. Of course *any multiples of these numbers may be used.* Gauss' methods are too difficult to be treated here.

The reader will note that the italicized statements are false.

A limitation in the possibilities of the science of geometry, or in the capacity of the student is suggested by the next note quoted. The reference to the necessity of using a protractor is somewhat serious in view of the possibility of missing the spirit of classical geometry by invoking an instrument other than a straight edge and pair of compasses. We read:

> Theorem 2, page 232 [If a circle is divided into n equal parts, the chords joining successive points of division form a regular inscribed polygon.] tells how to inscribe a regular polygon of n sides in a circle. The circle can be divided into n equal arcs by dividing the angle at the center, 360°, into n equal parts. Hence whenever the angle $360°/n$ can be constructed by compasses and ruler alone, the polygon can be constructed by compasses and ruler. Otherwise a protractor must be used.

Observe in the following remark that the position of the phrase "the numbers of whose sides are prime numbers" spoils the correctness of the statement:

> The only other regular polygons [insert phrase here] which can be constructed by means of compasses and straight edge alone were shown by Gauss (1777–1855) to be those **the numbers of whose sides are prime numbers** represented by the expression $2^{2^n}+1$. This adds only three numbers (17, 257, 65537) which are less than 10 billion billion.

In the midst of a lengthy discussion, which is substantialy correct, one notes the remarks:

> The results [i.e., of Gauss] showed that the number of sides must be:
> (1) A number of the form 2^n, as 4, 8, 16, 32, · · · .
> (2) A prime number of the form $2^{2^n}+1$, as 3, 5, 17, 357, · · · .
> (3) A product of such prime numbers without squaring as 15, 51, 85.
> (4) 2^n times the numbers in (2) and (3) as 6, 12, 24, · · · ; 10, 20, · · · .
> Write the numbers from 3 to 20, and put a check over the numbers which occur in (1), (2), (3), or (4) and a cross over the numbers which do not occur in (1), (2), (3), or (4). Polygons which have the numbers marked with a cross as the number of sides, cannot be constructed with a straight edge and compasses alone, by *methods which can be proved geometrically* · · · .

The italicized phrase would be less absurd if it were replaced by the words "are approved of." Perhaps (3) could be less ambiguously stated.

Two of these texts merely state that Gauss added the polygon of seventeen sides to the list of constructible regular polygons. Another adds that

> A German mathematician named Gauss published a proof in 1801 that a regular polygon of 17 sides and certain other regular polygons could be so constructed.

Three of the texts state only the sufficiency and omit the necessity of the Gaussian criterion for constructibility, e.g.:

> Gauss (1772–1855) made many investigations into the theory and subject matter of mathematics. He discovered that it is possible to construct regular polygons of $2^m \times (2^n+1)$ sides (where m and n are integers and 2^n+1 is prime), with ruler and compasses.

Finally two texts, besides the one first quoted, correctly state the Gaussian criterion for the construction of polygons of a prime number of sides, but fail to indicate the range of application as is given in certain of the others, to wit:

> Gauss . . . proved that regular polygons with a prime number of sides could be inscribed in a circle by means of a ruler and compasses if, *and only if*, the prime number was of the form 2^n+1.

The ten remaining texts make no remark whatever concerning the range of constructibility of the regular polygons. This seems somewhat unfortunate, for the student, and frequently also the teacher, wonders why only certain polygons are treated and others neglected in this chapter of plane geometry; indeed, many of our teachers of mathematics in high schools have had little opportunity to consider these elementary topics from an advanced point of view. To those who desire a concise summary of the facts concerning the constructibility, by elementary geometry, of the regular polygons, the concluding paragraphs are addressed. The reader is then invited to pass judgment upon the opinion of the writer that of the texts listed above attempting to shed additional light on this subject NONE is completely satisfactory. After a review of the historical details a brief synopsis is submitted for the high school student.

The Greek founders of classical (i.e., by ruler-and-compasses) geometry most probably knew as early as 460 B.C. how to construct the regular polygons of 3, 4, 5, 15, sides and those obtained by repeatedly doubling these numbers for the number of sides. Book IV of Euclid's Elements, compiled about 300 B.C. shows the constructions of the polygons of 4, 5, 6, and 15 sides.

The contributions of Gauss were made about 2100 years later. The first entry in a sort of daybook which he kept reads as follows:

> 1796
>
> Principia quibus innititur sectio circuli, ac divisibilitas eiusdem geometrica in septemdecim partes &c.
>
> Mart. 30 Brunsv.

i.e.,

1796

Principles upon which depend the division of the circle, and the geometrical division of it into seventeen parts.

March 30, Brunsw[ick]

Here we observe the date of the advent of the polygon of 17 sides as known to be constructible by elementary geometry.

In the *Disquisitiones Arithmeticae*, an epochmaking work of over 450 pages in Latin on the theory of numbers and applications, published at Leipsig in 1801, Gauss shows that the algebraic treatment of the problem of constructing a regular polygon of a prime number of sides, n, resolves itself into the consideration of a series of auxiliary equations whose degrees are factors of $n-1$, the coefficients of each of which are rational in the roots of the preceding one. Consequently he shows that in case the original prime is of the form $2^{2^n}+1$, the series of equations are all quadratics and hence can be solved geometrically. In the final two paragraphs of the *Disquisitiones* we find a summary of the contributions of Gauss on this subject. We read, translating into English:

Divisions of the circle, which one may effect by means of quadratic equations or by geometrical constructions.

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And so in the course of the foregoing investigations, the division of the circle into n parts, if n is prime, has been reduced to the solution of as many equations as there are factors of $n-1$, the degrees of the equations being equal to these factors. Accordingly, whenever $n-1$ is a power of 2, which happens for n equal to 3, 5, 17, 257, etc., the division of the circle is reduced to quadratic equations, and the trigonometric functions of $360°/n$, $720°/n$, etc., are expressible by means of square roots (their complexity depending upon the size of n); hence in these cases the division of the circle into n equal parts, or the construction of the regular polygon of n sides is clearly possible by geometric means. For example, for $n=17$, the cosine of $360°/17$ is readily obtained:

$$-1/16+1/16\sqrt{17}+1/16\sqrt{34-2\sqrt{17}}$$
$$+1/8\sqrt{17+3\sqrt{17}-\sqrt{34-2\sqrt{17}}-2\sqrt{34+2\sqrt{17}}};$$

the cosines of multiples of these angles have a similar form, the sines however involve an additional radical. It is indeed remarkable that although the division of the circle into 3 and 5 parts by geometry was known in the time of Euclid, nothing was added to these discoveries during the intervening 2000 years, all geometers assuming it as certain that, except for these divisions [3, 5] and those which follow directly from them, namely $15, 3\cdot 2^\mu, 5\cdot 2^\mu, 15\cdot 2^\mu$ and 2^μ, no others were possible by geometric construction. Moreover it is easily proved that if the prime number is written in

the form 2^m+1 the exponent m itself cannot contain other prime factors than 2; it must be either 1 or 2 or a power of 2; for if m contained an odd factor ζ (greater than 1) and $m=\zeta\eta$ then 2^m+1 would be divisible by $2^\eta+1$, and n would be necessarily composite. Accordingly all values of n which lead to quadratic equations are included under the form $2^{2^\nu}+1$. Hence by setting $\nu=0, 1, 2, 3, 4$, or $m=1, 2, 4, 8, 16$, we obtain $n=3, 5, 17, 257, 65537$. By no means will *all* numbers of this form $[2^{2^\nu}+1]$ indicate divisions of the circle which can be effected geometrically, but only those which are *prime*. Indeed Fermat, misled by induction, had asserted that all numbers of that form $[2^{2^\nu}+1]$ are necessarily primes; the illustrious Euler was the first to observe that this was erroneous, since for $\nu=5$, or $m=32$, $2^{32}+1$ [or $2^{2^5}+1$] $=429496729$, a number containing the factor 641.

But whenever $n-1$ contains other factors besides 2, higher equations [than quadratics] arise, e.g., one or more cubic equations result if 3 occurs once or more frequently as a factor of $n-1$, a quintic equation is encountered if $n-1$ is divisible by 5, etc. WE CAN ESTABLISH RIGOROUSLY THAT THESE HIGHER EQUATIONS CAN BE NEITHER AVOIDED NOR BE REDUCED TO LOWER ONES, and although limitations of space exclude a demonstration of this fact here, still we consider it advisable to sound a warning lest anyone should hope to effect other constructions than those which our theory supplies, e.g., divisions into 7, 11, 13, 19, etc. parts, and so waste his time.

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"If the circle is to be divided into a^α parts, a being prime, it is clear that this is possible if $a=2$, and impossible for any other value of a if $\alpha>1$, for then in addition to those equations encountered in the division of the circle into a parts it is necessary to solve $\alpha-1$ others of degree a; moreover these cannot be avoided or depressed. And so the degrees of the required equations can be noted generally by the prime factors of $(a-1)a^{\alpha-1}$ (as is likewise apparent when $\alpha=1$).

Finally if the circle is to be divided into $N=a^\alpha b^\beta c^\gamma \cdots$ parts, $a, b, c, \cdots$ denoting different primes, it is sufficient to effect divisions into a^α, b^β, c^γ, etc. parts. To ascertain the degrees of the equations required for this purpose it is necessary to consider the factors of

$$(a-1)a^{\alpha-1},\ (b-1)b^{\beta-1},\ (c-1)c^{\gamma-1},\ \text{etc.}$$

or the factors of the product of these numbers, which amounts to the same thing. We note incidentally that this product expresses the number of numbers less than N and prime to N [generally represented by $\phi(N)$]. Accordingly the division is possible geometrically only when N is a power of 2; indeed when N contains prime factors besides 2, say p or p', equations of degrees p or p' cannot be avoided. Hence one may infer in general that if the circle is to be divided geometrically into N parts, N must be either 2 or a power of 2, *or* a prime of the form 2^m+1, *or* a product of primes of this form, *or* a product of one or more such primes by 2 or by a power of 2; or briefly, it is necessary that N involve no odd prime factor which is not of the form 2^m+1, nor a repeated prime factor of the form 2^m+1.

There are 38 such values of N less than 300: 2, 3, 4, 5, 6, 8, 10, 12, 15, 16, 17, 20, 24, 30, 32, 34, 40, 48, 51, 60, 63, 68, 80, 85, 96, 102, 120, 128, 136, 160, 170, 192, 204, 240, 255, 256, 257, 272.

We note then that Gauss established the possibility of constructing polygons having a prime number of sides if the prime is of the form 2^m+1; furthermore he showed the possibility of constructing regular polygons of N sides if N contains only prime factors of the form 2^m+1, none repeated, besides the factor 2^n. He also stated that rigorous proof could be offered that no other regular polygons could be geometrically constructed.

A proof of this fact, namely, that no other regular polygons than those of Gauss are constructible be elementary geometry, was published by Professor J. Pierpont, of Yale University, in a paper entitled "On an Undemonstrated Theorem of the Disquisitiones Arithmeticae," [*Bulletin of American Mathematical Society*, v. 2, 1895, p. 77–83]. In this paper the necessary and sufficient criterion for the construction of regular polygons by the use of rational conics is also developed, conics being excluded from elementary geometry. The criterion states that a regular polygon of n sides can be constructed by the use of rational conics if and only if the function $\phi(n)$ contains no prime factor other than 2 or 4.

Accordingly all the various notes on this topic in the geometry texts listed above may be modified to indicate that

(1) Polygons having a prime number of sides may be constructed geometrically if, *and only if*, the prime number has the form $2^{2^n}+1$.
(2) Polygons having a composite number of sides, N, may be constructed by elementary geometry if, and only if, the odd prime factors of N are unrepeated and of the form $2^{2^n}+1$.
(3) To date only 5 regular polygons having a prime number of sides are known to be geometrically constructible, namely those of 3, 5, 17, 257, and 65537 sides, for these are the only prime numbers known which are expressible in the form $2^{2^n}+1$.

Little, Brown and Company (inc.) announce that Mr. James W. Shreman, who has been associated for twelve years with their Educational Department, has recently been made Manager of that Department.

TREND IN ENGINEERING EDUCATION*

By A. A. Potter
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Need for Education in a Democracy—The growth in the density of the population of the U.S.A. has gone on simultaneously with a more general appreciation of education. It has always been our American faith that an educated electorate is the corner stone of a successful democracy. While during recent months in the hysteria of drives for lower taxes and government economy, the educational system of this country has received a severe setback, the faith of our people in education is still undimmed. The average American is anxious to afford the youth of our country such educational advantages as will enable them to discharge most effectively their obligations as citizens.

There is a greater realization at present than ever before that the mental and moral discipline formerly belonging to the home has to be supplied by formal education. In the days past when our wants were few, when the necessities of life were supplied by hand labor, when the home was the educational center as well as the social and industrial center, the independence of the individual made his education of no concern to the public. The interdependence of modern life and the difficulty of keeping our social organization and our economic structure properly balanced makes the future of our country greatly dependent upon the type of education our youth is receiving.

Only those who have no conception of the place of education in a democracy are willing to sacrifice the future of our youth in order to cover up extravagances in certain of our governmental activities. If the world of tomorrow is to be an improvement of that in which we are living, it is up to all of us not to disregard the education of youth by false economies and by the neglect of our teachers who are shaping the careers of the citizens of tomorrow. The education of our youth cannot be postponed or decreased in effectiveness without paying great penalties in the days to come. Education represents our hope in the future, is our chief bulwark against the destructive forces of

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* Editor's Note.—Read before the Chemistry and Physics Section Indiana State Teachers' Association, October 19th, 1933. This paper is of such general interest (although its title suggests a special engineering slant), that it is presented for the thoughtful consideration of many science teachers. F. B. Wade.

extreme radicalism, and has as its main objective the promotion of well being and the highest qualities of life. H. G. Wells' statement that "civilization is a race between education and chaos" is most timely.

Engineering and Engineering Colleges—With reference to scientific and engineering education, it should be realized that whether people like it or not, they are destined to live and to work in an environment which is being affected more and more by science and by engineering. This means that those who are interested in living intelligently and happily in the present civilization must have an understanding of science and of engineering which, to an increasing extent, will affect their environment. After all, the most successful people are those who have the wisdom to adjust themselves to understand and to live most happily in the environment in which they have to live. Thus the study of science and of its applications to engineering may be considered as the best type of preparation for successful living in our present civilization. It is the true modern type of liberal education.

The engineer of today touches the life of every individual in an industrial nation, and our economic order is dependent upon him to organize human effort, so that the forces and energies of nature are utilized most effectively in the service of mankind. The engineer is assuming a most important role in the lives of civilized people, and it is expected that his activities should definitely improve our social order. Accordingly, the preparation of the engineer is of general concern, as his work affects human happiness.

Arthur James Todd, in the Preface to his Theories of Social Progress, stated: "If humanity is to hold the threads of its own destiny and rise from ages of blind drift to a place of mastery, it will be through the discovering and utilizing new types of education." The improvement in our standards of living has gone on simultaneously with a more general appreciation of scientific and engineering education.

Engineering education, other than military, a newcomer in professional education, was started in this country at the Rensselaer Polytechnic Institute in 1824 and by 1862 five additional engineering colleges were added. The Morrill Land-Grant Act, signed by President Lincoln in 1862, provided means for rapid extension of engineering education and made this type of education widely accessible to the industrial classes. From 1862

to 1880 the number of engineering colleges increased from six to eighty-five, and by 1929 to over 150, with an enrollment of about 60,000 students.

Engineering was the first profession to organize a society devoted to the improvement of collegiate teaching, the S. P. E. E. having been started in 1895. The rapid growth in the number and in the enrollment of the engineering colleges of this country during the past seventy years is an indication that there has been public approval of the type of education offered by these institutions. To an increasing extent, industries, utilities and public works are dependent upon graduates from engineering colleges not only for the solution of their technical and scientific problems, but also for executive and administrative posts.

The development of the engineering college in type and in effectiveness was not the result of active interest on the part of the profession of engineering, but has followed closely the proggress of science, industry and the engineering profession. In a sense, it was brought about as a result of the recognition on the part of the public of the importance of applied science.

With the increasing complexity of modern industries and their constantly growing dependence upon technological improvement and new leadership, they are bound to have an increasingly direct interest in the product of engineering colleges. Engineering educators are dependent upon industry to keep their institution abreast with the times and their research activities most effective.

Science and Engineering—This year millions of people visited the Exposition, A Century of Progress. The last century and particularly the forty years which have elapsed since the first great World's Fair was held in Chicago have been particularly significant on account of the great increase in man's material possessions which have been made possible by science and engineering. Radios, moving pictures, Diesel engines, aeroplanes, electric refrigerators and modern production methods were unknown in 1893, electric power was only eleven years old, and the steam turbine, the automobile, electric traction and electric welding were in their infancy. These and other great contributions in engineering which have been made by engineers and by inventors were made possible by the foundations laid by physicists, chemists and other scientists, and the achievements of the engineering profession of tomorrow can only be

kept at a high level by new scientific knowledge. The engineer of today is constantly using more and more scientific knowledge, while physicists and chemists are becoming interested to an increasing extent in the engineering applications of science. Thus science and engineering are absolutely interdependent and the future progress of one depends upon the other.

Present Engineering Curricula—The interest of engineering colleges has, until very recently, centered in undergraduate instruction. Some of the weaker of these institutions stressed vocational and practical training, but the better engineering colleges realized the difference between training and education, and stressed the development of the student's reasoning power without regard to his immediate usefulness after graduation. No effort was made by the best of these colleges to turn out a finished product, but to prepare their graduates for largest ultimate development and for greatest usefulness in the long run. The program of studies is made up so that the student devotes about half of his time to science, mathematics and the so-called humanities, and about an equal amount of time to technology. Physics, chemistry and mathematics have always been considered the foundation subjects of the engineer's preparation.

Until very recently the great demand for engineering college graduates with bachelor's degrees and inadequate recognition on the part of industry and the engineering profession of resident graduate study have been responsible for the small number of engineers who held advanced academic degrees. Graduate study has received a new impetus in connection with the development of engineering research at institutions of higher learning and was also stimulated by the realization of some industries that advanced scientific knowledge is a necessity for their future development. Growth in engineering graduate courses has been particularly noticeable since 1930, as engineers out of employment are striving to improve their preparation in order to be ready for greater responsibilities when industrial conditions improve.

Most of the undergraduate and graduate curricula lead to degrees in chemical, civil, electrical, mechanical and mining engineering. In some institutions specialized undergraduate curricula are offered in aeronautical, agricultural, architectural, building, ceramic, highway, railway and other specialized branches of engineering. Several institutions also offer special

undergraduate curricula in industrial or administrative engineering. About ten per cent of the total engineering students of this country are pursuing cooperative engineering courses which combine practical experience with scholastic training; there seems to be no difference in the results secured with cooperative and all-resident curricula. Nearly two-thirds of all engineering students are pursuing curricula which lead to degrees in civil, electrical and mechanical engineering, and the enrollment in chemical engineering during recent years has been increasing very rapidly.

There has been a tendency on the part of engineering educators to magnify the differences in civil, electrical, mechanical and other branches of the engineering profession. As early as 1893 the President of the A.S.M.E., E. B. Coxe, in his annual address stated that "the position which the successful engineer occupies does not depend upon whether he graduated as a C. E., E. E., M. E., etc., but upon the fact that he has a mind and has had a training which has enabled him to develop in a particular direction." It should also be recognized that the work of the engineer in practice is organized largely along functional lines of research, design, production, operation and sales rather than in the fields of demarcation followed by our engineering societies.

Problems Before Engineering Colleges—The activities of the engineering profession in connection with the present period of readjustment have resulted in a general belief that the present economic unbalance can only be corrected by the engineer. The engineer, who has contributed greatly to the improvement of the material welfare of humanity is expected to bring about a better economic order and to take a most active part in the solution of the problems which affect the civilization of his creation. During these changing conditions the engineer of tomorrow must be prepared not only to take his place among the best educated leaders of other professions, but must be ready to assume great economic and social burdens in order to aid in bringing about permanency for our civilization.

The engineering colleges have a great responsibility to meet the demands of our times so that their graduates will not only be capable as engineers, but professional people who are familiar with the trends in human progress and who will be able to take an active and leading part in building a rational world.

To meet increased competition for positions of responsibility

our graduates of the future will have to be more thoroughly prepared in the fundamental sciences, will have to be able to express themselves more clearly and correctly, and will be expected to have a better appreciation of economic forces and social values. We must realize that the main objective of engineering education is the preparation for successful living in our scientific age. Thus the basic instruction in mathematics, science, English, economics and technology should be more thorough, and the graduates must show a greater interest in aesthetic and intellectual matters.

Cooperation of Secondary Schools—Teachers of science and of mathematics in the secondary schools can serve science and engineering most effectively by working for greater thoroughness on the part of those who are interested in engineering as a career. Those young people who are superficial, have difficulty with mathematics, are not definitely interested in science, and who are looking for easy lives or for short cuts to success, should be advised against attending an engineering college. Just because a boy is a good mechanic is no indication that he will be a successful engineer; in fact, too great an interest in things may prove the opposite. Interest in knowledge and curiosity about the laws which govern things are usually a fair indication of engineering aptitude. Those who show proper aptitude for engineering should be advised to include in their secondary school course four years of mathematics, one year each of physics and chemistry, four years of English, two years of history and at least three years of Latin, German or French. As an aid to the development of greater thoroughness, high school courses in physics and chemistry should be planned so that the student has to work a considerable number of numerical problems, making use of the mathematics of at least the two lower high school classes. Greater cooperation between teachers of science in secondary schools and of those in engineering colleges should prove most helpful in insuring better entrants to engineering colleges.

Cooperation with the Engineering Profession.—During these changing conditions the engineering profession realizes that the engineer of today must not only be able to take his place among the best educated of other professions, but must be ready to assume great social and economic burdens in order to aid in insuring the permanency of our civilization. Thus the engineering societies are interesting themselves to a greater extent than

ever before in the preparation of the engineer. In the past the engineering profession, as such, has not taken a very active part in shaping or in directing engineering education. The aid given up to date to engineering colleges has been informal, has not represented well developed concerted action, and has generally impressed the governing bodies of colleges and universities as having little, if any, of the weight of the profession back of it.

During the past year steps have been taken which it is hoped will result in enhancing the professional status of the engineer. The major engineering societies are now cooperating in a movement designated as the Engineers' Council for Professional Development, which has placed before itself four objectives:

1. Insure that only properly qualified young people seek admission to engineering colleges.

2. Bring about effective cooperation between the engineering profession and engineering education.

3. Aid the young engineer in development to full professional status by post scholastic education and by professional contacts.

4. Insure proper recognition for the engineer who has attained full professional status.

The above program is definitely focused upon the education preparation of the engineer, from the period before his entrance to college through his early years in practice and until he is ready to receive professional status.

No progressive American believes that the last frontier has been reached or that America has passed its zenith of greatness. The tremendous natural resources of this country, the creative and inventive talent of our people, our gift of utilizing science and machinery, and the good sense of the average American not to be carried away by false doctrines will all combine in bringing back, before long, better and more prosperous times than ever before. Active cooperation of the best educated and most intelligent citizens should result in bringing about in the future a more general well being than the world has ever known before, and in the new and better era which is bound to come, those working in the fields of science and engineering will play a most prominent role.

The test of a teacher is in the character and lives of the men and women who were at one time his students—*Arthur L. Foley.*

THE AMMONIA SYSTEM OF COMPOUNDS

By Henry Wolthorn
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From a comparison of the physical properties of liquid ammonia and water, it becomes apparent that these two solvents have much in common. In a previous paper[1] it was shown that, like water, liquid ammonia is an excellent solvent and reaction medium. In this paper we wish to show that just as a large number of inorganic and organic compounds may be thought of as derived from water, so there is a similar system of compounds derived from ammonia.

Water ionizes to give a hydrogen and a hydroxyl ion:

$$H_2O = H^+ + OH^-$$

If the hydrogen ion is replaced by a strongly electropositive element, a base is formed, or more accurately, an aquo base. Similarly, ammonia ionizes to give a hydrogen and an amide ion.

$$NH_3 = H^+ + NH_2^-$$

If the hydrogen ion in ammonia is replaced by an electropositive element, we get an ammono base:

$$K + H_2O = KOH + \tfrac{1}{2}H_2$$
$$K + H_3N = KNH_2 + \tfrac{1}{2}H_2$$

As may be seen from the equations, the formation of the aquo base potassium hydroxide and the ammono base potassium amide, are exactly analogous. In both cases hydrogen is evolved. But since ammonia is ionized to a much lesser extent than water, the second reaction is considerably slower, and a catalyst of iron oxide is used to hasten it.

In its reactions potassium amide is a typical base. It conducts the electric current readily. It changes the color of indicators. Phenolphthalein in liquid ammonia turns red when a drop of potassium amide solution is added. It precipitates insoluble amides, imides, and nitrides, just as in water potassium hydroxide may precipitate insoluble hydroxides or oxides.

$$Mn(SCN)_2 + 2\ KNH_2 = Mn(NH_2)_2 + 2\ KCNS \qquad \text{(amide)}$$
$$PbI_2 + 2KNH_2 = PbNH + 2\ KI + NH_3 \qquad \text{(imide)}$$
$$3\ HgI_2 + 6\ KNH_2 = Hg_3N_2 + 6\ KI + 4\ NH_3 \qquad \text{(nitride)}$$

[1] This Journal *33*, 288 (1933).

Many of the insoluble amides resemble the hydroxides in forming voluminous, gelatinous precipitates. Potassium amide can be used to neutralize acids in liquid ammonia:

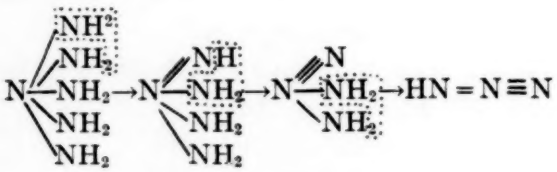
$$KNH_2 + H_2NCl = KHNCl + NH_3$$

It has also been recently shown that fused amides may be used to decompose silicate ores. Fused sodamide decomposes ores just as quickly and as thoroughly as does sodium hydroxide.

While the ammonium salts of the strong acids act as acids in liquid ammonia, they do not belong to the ammonia system of acids. Such compounds as hydrogen chloride, sulphate, and nitrate act as strong acids in all ionizing solvents. The acids of the ammonia system are the amides and partially deammonated amides of the electronegative elements. The following equations show the formation of nitric acid by successive dehydrations of ortho nitric acid:

$$N(OH)_5 \rightarrow ON(OH)_3 \rightarrow O_2NOH$$

The parallel reactions for the corresponding ammonia compounds are as follows:



The final product is hydazoic acid, or ammono nitric acid. And in its reactions it does bear a marked resemblance to aquo nitric acid. A mixture of ammonium azide and ammonium chloride in water behaves like aqua regia, slowly dissolving the noble metals.

Similarly, it may be shown that phospham, $HN=P\equiv N$, corresponds to meta phosphoric acid, $HO-P\lesseqgtr^{O}_{O}$, and guanidine, $HN=C(NH_2)_2$, to carbonic acid, $O=C(OH)_2$.

These ammono acids exhibit all the reactions characteristic of acids. They conduct the electric current readily. They give color reactions with indicators opposite to those of bases. They neutralize bases, giving salts and ammonia as products:

$$KNH_2 + HNPN = KNPN + NH_3$$

And they react with metals with the liberation of hydrogen:

$$Mg + 2\ H_2NCN = Mg(HNCN)_2 + H_2$$

When zinc hydroxide is treated with an excess of potassium hydroxide, it forms the soluble salt potassium zincate. The same is true for aluminum hydroxide and a limited number of others. However, due to the hydrolytic action of water and the great solubility of these salts, few of them have ever been isolated. When this reaction was tried in liquid ammonia, it was found that a similar salt was formed which could usually be isolated as a definite crystalline compound. The analogous reactions between zinc hydroxide, and potassium hydroxide on one hand, and zinc amide and potassium amide on the other, are given in the following equations:

$$Zn(OH)_2 + 2\ KOH = Zn(OK)_2 + 2\ H_2O$$
$$Zn(NH_2)_2 + 2\ KNH_2 = Zn(NHK)_2 \cdot 2\ NH_3$$

With aluminum amide, only one hydrogen is replaced by potassium when it is treated with potassium amide:

$$Al(NH_2)_3 + KNH_2 = Al(NH_2)_2NHK + NH_3$$

This salt is quite soluble and a solution of it has to be cooled considerably before it will crystallize out.

Lead imide also forms a crystalline salt when treated with potassium amide:

$$PbNH + KNH_2 + NH_3 = PbNK \cdot 2NH_3$$

While in the water system only a few of these metallates can be prepared, at least two dozen ammono metallates have been isolated, including such compounds as potassium ammono stannate, $Sn(NK)_2 \cdot 4NH_3$, potassium ammono cuprite, $CuNK_2 \cdot 3NH_3$, potassium ammono magnesate, $Mg(NHK)_2 \cdot 2NH_3$, potassium ammono argentate, $AgNHK \cdot NH_3$, potassium ammono calciate, CaNK, and even such unusual compounds as potassium ammono sodiate, $NaNK_2 \cdot 2NH_3$ and lithiate, $LiNK_2 \cdot 2NH_3$.

That these compounds are actually salts and not double amides has been shown by a study of the products obtained when a solution of one of these substances is electrolyzed. If they were double amides, both metals would be deposited at the cathode. Such, however, is not the case. Potassium is always deposited at the cathode and the other metal at the anode. Ionization, then, takes place as follows:

$$Zn(NHK)_2 = 2K^+ + Zn(NH)_2^=$$

Brief mention should also be made of the ammonobasic salts. When bismuth chloride is added to water, a basic chloride is precipitated:

$$BiCl_3 + H_2O = BiOCl + 2\ HCl$$

A similar reaction takes place with many salts in ammonia. Thus the well-known "infusible precipitate" is formed by the ammonolysis of mercuric chloride:

$$HgCl_2 + 2\ NH_3 = HgNH_2Cl + NH_4Cl$$

The thought will readily suggest itself to the reader that if we have a water or oxygen system of compounds, and an ammonia or nitrogen system, there should be many substances which will contain both oxygen and nitrogen, forming a class of mixed aquo ammono compounds. Just a few of these compounds will be mentioned. Nitramide, $O_2N \cdot NH_2$, is a mixed aquo ammono nitric acid; sulphamide, $O_2S(NH_2)_2$, a mixed aquo ammono sulfuric acid; and amido chromic acid, $(H_2N)CrO_2(OH)$, a mixed aquo ammono chromic acid. This will give one an idea of the large field of research opened to the chemist by this new concept of an ammonia system of compounds.

II. ORGANIC COMPOUNDS

The concept of an ammonia system of compounds has not been applied as extensively to organic chemistry as it has to inorganic. But as far as it has been applied, the results have been very gratifying.

Alcohols are usually considered as being derived from water by the replacement of one hydrogen by an alkyl group. Typical members of the three classes of alcohols are:

CH_3OH	$(CH_3)_2CHOH$	$(CH_3)_3COH$
Primary	Secondary	Tertiary

Similarly, we may think of one hydrogen in ammonia as being displaced by an alkyl group, with the resultant formation of an ammono alcohol. Typical members of the corresponding classes are:

CH_3NH_2	$(CH_3)_2CHNH_2$	$(CH_3)_3CNH_2$

But in addition to these three classes, we can also have mixed alcohols in ammonia, due to the trivalence of nitrogen:

CH_3 > NH < $(CH_3)_2CH$	CH_3CH_2 > NH < $(CH_3)_3C$	$(CH_3)_2CH$ > NH < $(CH_3)_3C$
Primary-secondary	Primary-tertiary	Secondary-tertiary

That these compounds are actually alcohols is shown by their reactions. Just as the alcohols are better solvents for

organic materials than water, and poorer for inorganic materials, so the amines, or ammono alcohols, are better solvents than ammonia for organic, and poorer for inorganic compounds. And just as many salts may have alcohol of crystallization, so even more of them separate with amines of crystallization: $AgCl \cdot CH_3NH_2$, $ZnCl_2 \cdot 4CH_3NH_2$, etc. One of the characteristics of alcohols is that they react with the alkali metals with the liberation of hydrogen. Similar reactions take place with the amines:

$$Na + C_2H_5OH = C_2H_5ONa + \tfrac{1}{2}H_2$$
$$K + CH_3NH_2 = CH_3NHK + \tfrac{1}{2}H_2$$

The characteristic group of ethers in the water system is an oxygen atom bound to two alkyl or aryl groups. So in the ammonia system, an ether would be a compound having a nitrogen atom bound to three alkyl or aryl groups, in other words, a tertiary amine, R_3N. Their similarity of behavior is illustrated by their relative solubilities in water and ammonia respectively. Low molecular weight alcohols are perfectly miscible with water, while the ethers are insoluble. Similarly, the primary amines are extremely soluble in ammonia, but the tertiary amines very much less so.

The aldehydes and ketones are characterized by an oxygen atom doubly bound to carbon. So the characteristic of ammono aldehydes and ketones will be a nitrogen atom doubly bound to carbon:

Aldehydes	Ketones
$CH_3CH=O$	$(CH_3)_2C=O$
$CH_3CH=NH$	$(CH_3)_2C=NH$
$CH_3CH=NR$	$(CH_3)_2C=NR$

The trivalence of nitrogen makes the relationship a little difficult to see in that more combinations are possible. And further, while the aldimines, like $CH_3CH=NH$, are true aldehydes in that they contain the $=C=N-$group, they also exhibit reactions characteristic of alcohols because there is a hydrogen atom attached to the nitrogen. This hydrogen, like that of alcohols, is readily replaceable by metals:

$$C_6H_5CH=NH + KNH_2 = C_6H_5CH=NK + NH_3$$

The ammono aldehydes exhibit the same characteristic reactions as those of the water system. They have a strong tendency to polymerize. They may be reduced to the corresponding ammono alcohols:

$$C_6H_5CH=NC_6H_5+2\ H=C_6H_5CH_2\cdot NH\cdot C_6H_5$$

The Cannizzarro reaction takes place just as with aquo aldehydes:

$$2\ C_6H_5CHO+KOH=C_4H_5CH_2OH+C_6H_5COOK$$

$$2\ C_6H_5CH=NH+KNH_2=C_6H_5CH_2NH_2+C_6H_5C\ (NH)\ NHK$$

Benzoin condensation, characteristic of aldehydes, also occurs with ammono aldehydes. Other reactions exhibited by both types of aldehydes are the formation of addition products with sodium acid sulfite, the formation of oximes and hydrazones, and the reaction with the Grignard reagent to form secondary alcohols:

$$C_6H_5CHO+C_2H_5MgX=\begin{matrix}C_6H_5\\C_2H_5\end{matrix}\!\!>\!CH\cdot OMgX \xrightarrow{H_2O} \begin{matrix}C_6H_5\\C_2H_5\end{matrix}\!\!>\!CHOH+XMgOH$$

$$C_6H_5CH=NC_6H_5+C_2H_5MgI=\begin{matrix}C_6H_5\\C_2H_5\end{matrix}\!\!>\!CH\cdot NC_6H_5\cdot MgI \xrightarrow{H_2O} \begin{matrix}C_6H_5\\C_2H_5\end{matrix}\!\!>\!CH\cdot NH\cdot C_6H_5+IMgOH$$

Since the characteristic group of organic acids is the carboxylic $-C\begin{matrix}OH,\\O\end{matrix}$ any substance containing the group $-C\begin{matrix}NH\\NH_2\end{matrix}$ should exhibit acid properties in ammonia. Two such substances are acetamidine $CH_3C\begin{matrix}NH\\NH_2\end{matrix}$, and benzamidine $C_6H_5C\begin{matrix}NH\\NH_2\end{matrix}$. Both react with potassium amide, forming potassium ammono acetate and benzoate respectively:

$$R-C\begin{matrix}NH\\NH_2\end{matrix}+KNH_2=R-C\begin{matrix}NH\\NHK\end{matrix}+NH_3$$

The same compounds may be formed by the direct addition of potassium amide to nitriles, since the latter are the anammonides of the carbazylic acids:

$$R—C\begin{matrix}NH_2\\NH\end{matrix}=R-C\equiv N+NH_3$$

$$C_6H_5CN+KNH_2=C_6H_5C\begin{matrix}NH\\NHK\end{matrix}$$

The close analogy between the two types of acids is strikingly illustrated by the following reaction:

$$CH_3C\begin{matrix}=O\\ \diagdown OK\end{matrix} + KOH = CH_4 + K_2CO_3$$

$$CH_3C\begin{matrix}=NH\\ \diagdown NHK\end{matrix} + KNH_2 = CH_4 + K_2CN_2 + NH_3$$

Esterification and saponification take place in ammonia as they would in an aqueous solution.

$$C_6H_5C\begin{matrix}=NC_6H_5\\ \diagdown NH_2\end{matrix} + C_6H_5NH_2 = C_6H_5C\begin{matrix}=NC_6H_5\\ \diagdown NHC_6H_5\end{matrix} + NH_3$$

$$CH_3C\begin{matrix}=NC_6H_5\\ \diagdown NHC_6H_5\end{matrix} + 2\ NH_3 = CH_3C\begin{matrix}=NH\\ \diagdown NH_2\end{matrix} + 2\ C_6H_5NH_2$$

The first equation represents the reaction between an acid ester of ammono benzoic acid and an ammono alcohol to form the diphenyl ester of ammono benzoic acid. The second represents the ammonolysis (saponification) of an ester of ammono acetic acid to ammono acetic acid and ammono phenol.

Just as with inorganic compounds we found that many could be looked upon as mixed aquo ammono compounds, so also with organic substances. Of these, the amides, $R-C\begin{matrix}=O\\ \diagdown NH_2\end{matrix}$, are the most common. Other mixed aquo ammono acids are biuret, $OC\begin{matrix}\diagup NH_2\\ \diagdown NH\\ \diagup NH_2\end{matrix}OC$, and benzene sulfonamide, $C_6H_5SO_2NH_2$.

In this paper we have tried to briefly develop the idea of a system of compounds, both organic and inorganic, which might be thot of as derived from ammonia just as most ordinary substances are derivable from water.

ANOTHER ALPHABET

By Ross McConnehey

In the new deal we have NRA, AAA, RFC, HOLC, etc. but in physics we have

C.G.S.	E.M.F	R.P.M.	D.P.S.T.
K.E.	C.	Y.	P.D.
X.	M.A.	Q.S.T.	Z.
S.H.M.	F.P.S.	K.	C.W.
D.X.	I.C.W.	L.	M.M.F.
B.T.U.	A.C.	A.F.	R.M.S.

UNUSUAL DEMONSTRATION EXPERIMENTS

By J. O. Frank
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AND

Guy J. Barlow
Principal McKinley Junior High School, Appleton, Wisconsin

The lecture demonstration is recognized as a very important phase of science teaching, yet comparatively little has been written describing its technique. The demonstration is ordinarily thought of as an experiment carried out by the instructor in the classroom before the class. Explanation, questions or other remarks may or may not accompany the actual experiment. Other methods of using demonstration experiments have but rarely been described in the literature of science teaching.

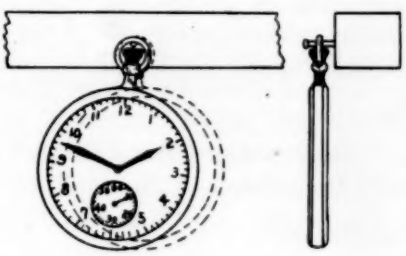
In the following pages an unusual method of using the demonstration experiment is described and experiments suited to the method are given.

PROBLEM AND MYSTERY DEMONSTRATIONS

One method of inducing interest in a new phase of science is to prove to the student that it affords explanation of facts or phenomena not ordinarily understood. Merely telling the students this does not suffice, as the "Oh Yeah" attitude is often the result. But when the teacher can show something which at first looks to be very ordinary but which on further investigation cannot be easily explained—the student is usually interested. And some students will be so intrigued by the problem offered that they will be driven to study, experimentation and other extra effort—until a satisfactory solution is found. An unsolved problem which is only an unsolved problem offers little challenge—the student may simply dismiss it with the thought "this is not in my field—it is a problem for somebody else to solve." But an unsolved problem, which has to do with unusual aspects of ordinary things, which offers something hither-to unnoticed about familiar objects or materials—that arouses interest at once. On this fact is based much of the interest in detective stories and in puzzles (crossword and otherwise). Let us illustrate:-

THE SWINGING WATCH

What is Seen:



A watch is hung on a small nail in such a way as to be free to move sidewise. Students are asked to observe carefully what happens. The watch begins to sway with a pendulum-like motion and with an amplitude which increases to a maximum and then decreases until no motion is seen. Then the cycle is repeated.

Explanation:

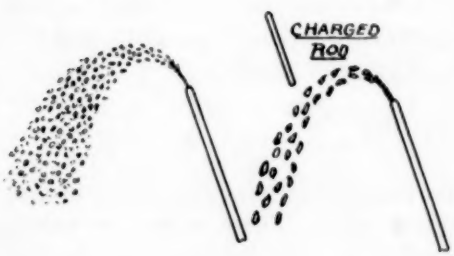
The watch acts as a simple pendulum whose oscillations are caused by the balance wheel which acts as a secondary pendulum.

In using this experiment the teacher may simply hang the watch on a small nail and ask the pupils independently to note, record and explain what happens. After several minutes of observation the watch will be removed and a pupil asked to write on the board briefly but exactly what happened. Other pupils will correct and extend the record of the facts observed. (Great differences in ability to observe will be noted. Some pupils are careful, others careless, some see little, others much.)

Out of the reports of the various students will come much interesting and profitable discussion. Some teachers will find it well to prepare a list of questions and to ask the students to find the answers to these questions which all relate to the facts observed.

A MAGIC WAND

What Is Seen:



Water is thrown from a glass tube, drawn to a point, in such a way as to form a spray of very fine drops almost approaching the appearance of mist. This spray is thrown into

the air and the water permitted to fall into the sink. When the operator points a black rod towards the jet of water the drops are attracted by the rod at one time and at another the stream suddenly changes from small drops to large ones, or from several streams to one single one.

How Used:

This experiment may be used in explaining precipitation of rain from clouds or the condition of colloidal suspension.

Explanation:

The fine spray consists of fine drops of water which are all charged alike electrically. This charge is strong at the upper part of the spray. Hence the drops repel each other and so do not coalesce. The rod used by the demonstrator is of ebonite and has been charged with static electricity. When brought near the spray the charges on the small drops are neutralized, they no longer repel each other and so coalesce quickly, forming larger drops. Near the point where the water leaves the glass nozzle, the drops of water are strongly charged and so strongly attracted by the ebonite rod sometimes flying several inches into the air to reach it.

Construction:

Use a glass tube 6 mm. in diameter drawn out to almost capillary dimensions. Attach this to water supply with a rubber tube about 4 ft. long. Control the force of the water by means of a pinch cock or else get water pressure by use of a syphon set at just the right height. Charge the ebonized rod by rubbing it with a piece of flannel or a cat's skin.

Some teachers will prefer to ask the pupils to explain what they have seen, then allow them to discover all additional facts by experiment and finally have them write a report explaining all the phenomena observed.

Other teachers will prefer to have the pupils reason, read and experiment in finding the answers to a list of questions and the solutions to problems which they will present.

A COLOR STUNT

What Is Seen:

Two colorless solutions are thoroughly mixed in a large beaker or flask on the demonstration table. There is no immediate color change but in a few seconds the solution suddenly changes

to a deep blue color. The operator is able to predict exactly when the color change will take place.

Explanation:

When iodic acid solution is mixed with sulphurous acid solution a reduction of the iodic acid, with the liberation of iodine takes place. If starch is present, blue starch iodide is produced. The reaction requires time to begin but takes place almost instantly once it does begin. Concentration and temperature are factors in determining the time of the reaction after the solutions are mixed.

Preparation:

1. Dissolve 10 grams of iodic acid in a liter of distilled water. Place in a glsss stoppered bottle labelled solution A. (Solution is very permanent.)

2. Bubble sulphur dioxide through 50 c.c. of water in a beaker till the solution is saturated with the gas. Pipette 25 c.c. of this into a glass stoppered bottle, dilute to one liter with distilled water and label it solution B. (Solution keeps only a few weeks.)

3. Pour 480 c.c. of distilled water (20 degrees C.) into a clean one liter beaker. To this add 70 cc. of solution A. (Iodic acid) and 1 c.c. of clear starch paste (freshly prepared). In another beaker mix 180 c.c. of solution B.(SO_2) and 320 c.c. distilled water. Mix each solution separately then pour them both quickly into a one liter cylinder and mix with a long clean piece of glass tubing. In a very definite time (almost exactly one minute) after mixing, the color will suddenly change to deep blue. Use a piece of white cardboard as a background and a light to show color if experiment is performed at night. By varying the dilution, the time of the reaction may be changed. Use metronome or pendulum to check time. By experimentation to determine the exact time, a very impressive demonstration can be prepared.

Chemistry students may be asked to determine just how this "stunt" was done. They may be permitted to examine and experiment with the solutions used. Then by study and experiment, they may carry the investigation to successful conclusion which is indicated when they can duplicate the demonstration as described above.

* * * *

The foregoing experiments have undoubtedly long been known to many teachers and have been used by some of them most advantageously. Most teachers are not familiar with many experiments suitable for demonstrations escept those included in the usual laboratory manual. In earlier numbers of "SCHOOL SCIENCE AND MATHEMATICS" a few of these less wide-known experiments have been described by teachers from time to time but the attempts to describe the experiments of this kind have been sporadic and unsystematic.

In outlining the above experiments the writers have offered them as examples of a type of experiment which may be used as problem demonstrations. Other similar experiments are undoubtedly known to almost every experienced teacher. Others who are willing to contribute worthwhile experiments of an unusual type to these pages are invited to send their contributions to J. O. Frank, State Teachers College, Oshkosh, Wisconsin. Comments or criticisms of any kind from teachers regarding experiments of the type described will also be gratefully received.

AMATEUR TELESCOPE MAKING AS A PROJECT IN HIGH SCHOOL PHYSICS

BY WILLARD GEER
Reedley Joint Union High School, Reedley, California

The challenge that constructing a telescope makes, the reward that it offers to the boys who master the task, and the patience and care required, make this project one of the most fascinating of all high school projects. Many have thought upon first consideration that the work of telescope construction would be too difficult for a high school boy, but the boys of this high school have even taken telescope production out of the project field and have adopted it as one of their hobbies.

Interest was started when the physics class of the high school decided in the winter season of 1931–32 to construct as a class project a small reflecting telescope of the same type used in the larger ones at Mt. Wilson. The size was decided upon, a pair of six inch discs were purchased along with the proper grinding powder, and work was started to hollow out a concavity in one of the discs to produce the mirror. This was done by the process of rubbing one disc, the thicker one, over the thinner one with a mixture of carborundum and water intervening. The

entire process is adequately described in the handbook, "Amateur Telescope Making" published by the Scientific American Publishing Company. The boys found that they could secure sufficient instruction and answers to all their problems in this book alone, but it might be here noted that there are other books, probably available in local libraries, which would prove as useful for guidance in this project.

Working in pairs during study periods and the noon hour, the grinding was finished within a month and the more intricate task of polishing and figuring was begun. Since no one of the students had had any experience in this before, many mistakes were made and this inevitably lengthened the time required to produce a good parabolic surface ready for the final silvering process.

However, the mirror was finished, at length, and the telescope tube was made and mounted in time for the annual school exhibit in the spring. On that occasion there were hundreds in the community, parents, patrons, and students, who saw for the first time in their lives such thrilling sights as the belts and moons of Jupiter, the phases of Venus, double stars, nebulae, and the impressive details upon the mountains of the moon, in fine distinction.

During the following year, after their experience on the group project, five boys started and finished telescopes of their own, and now the number under construction has reached a total of fourteen, ranging in size from small three inch mirrors cut from windshield glass to large eight inch reflectors, some of which are made of pyrex.

The most ambitious project of all, the construction of a fourteen inch mirror, was halted by the untimely accidental death of a boy who had already successfully completed a remarkably fine eight inch telescope with a polar mounting set in concrete, this instrument being equipped with accurate hour and declination circles.

The construction time required for these amateur telescopes depends upon the size of the mirror planned and the persistence of the boy, but a reasonable estimate for the average boy would probably predict from three to six months for completion of the project. However, taken in actual hours spent upon the work, one would estimate about ten hours for the rough grinding, five for the polishing, and from two to ten hours for the figuring, this last depending upon the luck encountered in avoiding

humps and hollows in the parabolic figure on the surface of the glass disc. As a project, it is recommended that ample time be allotted for its completion, with a steady amount of work each day, since the labor is tedious and monotonous if done for too long an uninterrupted period.

The mounting design will vary with the boy and his ingenuity in utilizing available materials, such as parts from old cars and scrap iron from junk yards.

A good six inch telescope such as a high school senior would make could not be duplicated commercially for hundreds of dollars, yet this one that the class constructed, cost, completely mounted, less than ten dollars. Most of the boys produce their own instruments at a cost ranging from less than a dollar for the three inch ones to five dollars for the larger ones.

When their mirrors are finished and mounted, the boys feel that they own valuable instruments. Commercial catalogue list prices place a six inch reflector at $750, while their small three and four inch telescopes run from $20 to $30. These amateur telescopes made by the students, when compared size for size, measure very favorably with or duplicate the performance of the commercial variety in magnifying power and definition. The small amateur instruments made of windshield glass are very satisfactory for terrestrial observation, but for astronomical work at least a six or eight inch mirror is needed. The large eight inch telescopes reveal as many hundreds of stars in their field as can be seen in the entire sky without the aid of the telescope. At Reedley three six inch mirrors and one eight inch are now being completed by students especially interested in astronomy.

It is unnecessary here to mention details of grinding and polishing or materials used in any part of the process, since these are best found in guide books devoted entirely to this purpose, and with the expenditure of some effort upon searching for them are available to any school or class. As a cooperative class undertaking which will yield invaluable rewards both in the way of added equipment to the school at small outlay of expense, and as an enjoyable, practical, and worthwhile project in illustrating work in physics or even in exceptional general science classes, the construction of amateur telescopes appears to have no equal.

As an individual project this work soon takes itself out of the field of suggested or assigned tasks, or even cooperative school

endeavor, and is transformed into a fascinating and a spell-binding hobby, wherein the developing and stimulated ambition of the boy leads him into new attempts at larger and better optical parts of his own manufacture for his larger and more perfected mountings, and into new fields of probing and peering into the realms of scientific knowledge—out of his own petty terrestrial problems into the "expanding universe."

ADVERTISEMENTS AS A TEACHING DEVICE IN GENERAL SCIENCE

By Robert B. Colvin
Pennsylvania State College, State College, Pennsylvania

Advertisements of nationally known products appearing in well known weekly and monthly periodicals offer an untapped source of material which may be converted by teachers of general science into a live, interesting and instructional teaching device. The lay-out, the colors, the diagrams and pictures, and the "copy" of modern magazine advertisements provide a wealth of science material to which general science students readily turn as they learn to use them for this purpose.

Above all else the text and pictures of advertisements make much of the scientific teachings concrete; it is a revelation to the student and sometimes to the teacher to find vividly portrayed by an advertisement in a magazine some principle which formerly was visualized only from the picture in the text or the teacher's diagram on the board. Further, advertisements tend to be more up to date in statements on topics studied in general science than the textbook which remains static for some years. Finding the recently discussed topic pictured in an advertisement or discussed in the write-up of the advertisement tends to accomplish two worthwhile ends. First, the principle taught becomes more real when illustrations applicable to the student's everyday environment are given and which were not found in the text. Second, because the principle taught is found in a new situation and often in a more vivid form, the idea becomes better fixed psychologically, especially if he has done something with the advertisement after finding it.

In the following paragraphs will be made a few suggestions of ways in which various advertisements have been used with the general science course. Space will not permit a detailed description of all the advertisements used during the term.

Following are some condensed statements of the various ways of using some frequent and some infrequent advertisements. (I) The simplest use to which advertisements can be put is to represent a scientific principle or present examples of a topic just completed. It is not to be expected that there can be found an advertisement comparable to every topic or principle considered in general science but the number to be found will be large. For example, a large unit in general science deals with air pressure and its behavior. An automobile advertisement showing by diagram the effect of stream-lining on the air currents about the car and the reduction of the low air pressure area in the rear and consequent reduction of resistance to be overcome fits in well with the study of air pressure. For the student to find it in the magazine is much more meaningful than to see it in the text. Again, the topic of kindling temperature is effectively portrayed by an insurance advertisement showing by photograph the result of an explosion caused by gas seepage from a street main and a kitchen pilot light. In the text of the advertisement are mentioned other materials of low kindling temperature capable of being ignited by an electric spark or open flame. The photograph accompanying the advertisement was most vivid and arresting. When the student finds the advertisement himself, as the result of the teacher's suggestion, he can place it in his notebook accompanying his discussion of the demonstration or experiment. Other pupils sometimes mount appropriate advertisements as those just mentioned and place them on the bulletin board with all others gathered during a semester of study.

(II) To serve as a basis, core, or motivation for a unit of study is a much more extensive purpose than the one suggested above. It is particularly adapted to certain units since magazine advertisements do not cover all topics studied. Units of study for which advertisements have been found valuable as the starting point are those of building materials, vitamins and nutrients, and health and diseases (especially as concerned with the control of bacteria by antiseptics, etc.). In the case of the first unit suggested, building materials, the pupils would have collected for some days in advance all the advertisements to be found which describe any building material; stone, copper and brass pipes, wall boards, roofing, etc. From such a collection, which has been found to amount to a tremendous number and cover a great range, would be gleaned all statements concerning the de-

sirable properties of the material, its source when stated, etc. Such information gathered from advertisements will usually cover all that the text says of the materials and usually more completely and realistically. In some of the advertisements will be found statements and characteristics which will then necessitate further study, probably from the text book. For example, this might be found to occur in advertisements dealing with building stones (granites and limestones) or with wall boards and similar products which insulate against sound, heat and fire. The reasons why these products possess such characteristics would cause the student to turn to the text. This is not a supposition but the way it actually "worked out." At the same time a representative advertisement of the various materials placed on the bulletin board gives the atmosphere for a few days of an architect's office. Again, such advertisements used to illustrate the notebook furnishes a concrete application of the laboratory demonstration findings or other notes.

(III) To present new facts, not met in the original study of the topic, is another valuable function of advertisements. This function may occur in conjunction with the first two suggestions above but can be a separate function itself. It furnishes a valuable activity for all students but especially the slower ones, who, as they watch the advertisements and become familiar with them, find from time to time statements about some topic which had been studied some time before but telling something new of which the text and teacher made no mention at the first time of study. The pleasure and interest of the student finding such information is always high.

One example can be mentioned here to illustrate this function. A study had been made of the conductivity of heat by metals and customary examples had been considered. Later an advertisement of aluminum utensils was found by a student, stating the high conductivity of aluminum. With this fact the class was already familiar. However, the advertisement further stated the interesting fact that water in an aluminum kettle would heat faster at the top and throughout than in ordinary kitchenware because the conductivity of the aluminum would carry heat up the sides and pass it into the top layers of water without waiting for the usual convection currents to occur. A simple idea, but it made a great impression on the students, especially the one who found the advertisement. It was accompanied by a colored, symbolic picturization of conduction which was the

most valuable portrayal of that topic that the writer has ever found. Advertisements of manufacturing druggists (Parke, Davis & Co., Squibb & Sons) and insurance companies are rich in new information of health, control of diseases, or the historical background of medicine, in which the advertisement due to its recency of publication is more up to date than the text can be.

The statement of these three methods of using advertisements may suggest other uses to teachers. A few final ideas concerning the utilization of advertisements might be made. One item not to be overlooked is the value of the pictures, drawings, photographs and symbolic portrayal of ideas; often these are the most valuable item in the advertisement as a teaching device. Such parts of the advertisements are particularly worth while in illustrating the students' notebooks. Beside the use for notebook illustration, they are very effective when used in groups on the bulletin board, either mounted on large sheets of cardboard by individual students (as examples of various foods containing vitamins) or representing the findings of the class as a whole on the unit. It will probably be necessary at the beginning of the term to give the students an advance summary of the units to be studied and suggest the use of the advertisements in the studies to come so that they may be on the watch for valuable contributions. A few sample illustrations shown to the class conveys to them the plan of use. Advertisements with appropriate pictures or statements will seldom be found at the right time so the teacher especially should be watchful for usable material. It is surprising how the collection of advertisements from two or three issues of any popular magazine will cover a majority of the usual topics in general science.

As a final thought it should be kept in mind that general science is concerned largely with the student's environment and surely our present environment is depicted in large measure in advertisements on a national scale appearing frequently in well known magazines. They are ever before the student in attractive color and print; therefore they can serve as material to be studied or examined, with the text book as a guide, authority or supplement. Probably, however, a factor worth much consideration by the teacher is that such a scheme is another means of keeping students' interest high by (1) the unusualness of using such "common" material as advertisements for study and (2) the fact that it provides something for the student to be

on the lookout for and to cut out and paste in his notebook, a factor holding a great appeal to general science students.

IS THIS THE SCIENTIFIC METHOD?

By Ira C. Davis
University High School, Madison, Wisconsin

ORIGIN OF THE PROBLEM

An eighth grade general science class had been performing some experiments in the laboratory to discover the effects of soap on hard and soft waters. As an outgrowth of these experiments one of the pupils raised this problem: "How can I find out how hard the water is we use at home?" This is a practical problem in Madison because the city water is obtained from deep wells and is considered "hard". Many homes have commercial water softeners. This pupil had heard his parents say many times, "Our softener does not seem to work very well." The parents had not tested the water to determine if it was really "soft".

When this problem was mentioned in class, the other pupils were interested in undertaking the same problem. Investigation revealed that the thirty pupils in class lived in homes where six different makes of commercial water softening tanks were used, or in homes in which water was supplied from wells, from cisterns, or directly from the city mains without being softened.

CONTROLS AND VARIABLES

The testing of the water used in each home became an individual problem for each pupil. It was agreed the problem should be undertaken but the question to be answered was, How can it be done?

I have held the opinion for some time that one of the outcomes of laboratory work should be the understanding of the fundamentals of experimentation. What is an experiment? On what basis is an experiment performed? How does an experiment differ from any other type of work? The necessity of having controls and variables in experiments and demonstrations had been mentioned many times. Emphasis had been made repeatedly on the necessity of observing what factors were controlled and what factor was allowed to vary (variable). The ne-

cessity of having only one variable had also been emphasized. I have visited many classes in high school science (some in colleges) in which the pupils had not heard of controls or variables and had no notion what they meant. I mention controls and variables here because I think it will help in understanding how the pupils developed the methods and techniques used in solving the problem.

ESTABLISHING THE CONTROLS

The pupils were asked to make suggestions in writing for solving the problem. Then they were asked to read their suggestions. One pupil said, "Place some of the water in a bottle and find out how much soap it takes to make suds." Another said, "Put some water in a beaker and add enough soap, one drop at a time, to make suds." Soon several of the pupils remarked that these suggestions were not satisfactory because they were not using the same quantities of water. Immediately other questions arose. Some of these questions were, How much water shall we use? How do we know when we have suds? Does shaking help to make suds? How can we add one drop of soap at a time so we will be sure that we are using the same quantities of soap? The question, What controls do we need, was then raised by the instructor. The pupils soon agreed that they needed to: (1) Use the same volume of water, (2) Add one drop of soap at a time, (3) Agree on amount of shaking, and (4) Agree when they had suds. What is the variable, the number of drops of soap needed to make suds with the different kinds of water?

After agreeing what factors needed to be controlled, the next problem was to set up the controls. It was agreed that a test tube filled with water to a depth of two inches was the volume of water to be used. (All of the test tubes used were taken from the same box.) Some suggested the use of graduates. Soap could be added, drop by drop, by the use of a stirring rod. Pipettes and medicine droppers were also suggested. A "shake" was demonstrated. It was agreed the test tubes should be shaken three times after the addition of each drop of soap. Suds were formed when they were one inch thick above the level of the water. The pupils had measuring scales in their mathematics textbooks so the problem of measurement presented no serious difficulties except for accuracy. All of the pupils used soap taken from the same bottle.

The pupils were now asked to write directions for solving the

problem and include the controls as agreed upon. Each pupil's directions were checked for accuracy and completeness before they were permitted to begin their laboratory work.

ESTABLISHING STANDARDS FOR RESULTS

In a real problem like this the answer is not known in advance. To establish results on which to form a basis for drawing conclusions, the pupils tested distilled water, lake water, city water, and the water used at home. The correct answer for distilled water was obtained by recording the number of drops of soap used by each pupil to get suds Twenty-seven of the thirty pupils used either two or three drops. Two drops was not quite enough and three drops was too much. The three remaining pupils repeated their experiments and discovered the mistakes in their techniques. In a similar way it was shown that five or six drops were needed to form suds with lake water, and seven or eight drops with city water. After establishing correct answers for the relative hardness of the three kinds of water, the pupils proceeded to determine the number of drops of soap needed to make suds with the water used at home. Each pupil made at least three trials and a large proportion of the pupils exchanged samples and tested the water for at least one other pupil as a check upon each others work. Results were recorded and on the basis of these results the pupils drew their conclusions. They were now in a position to judge the hardness of the water used at home as compared with distilled water, lake water, and city water. The pupils solved this problem in two class periods.

ACCURACY OF RESULTS

The simple techniques used seem to produce accurate results. They may not be as accurate as a trained chemist desires, but they are accurate enough for the problem at hand. In case of dispute the pupils were cautioned not to accept the results as final. In several cases the pupils discovered that the "softeners" used at home did not thoroughly soften the water. Some "softeners" did. In two cases it was discovered that the softeners were defective. Further investigations substantiated the results obtained by the pupils.

COST OF EQUIPMENT

Each pupil used two test tubes, a stirring rod and a small quantity of liquid soap. The total cost of the experiment need

not exceed ten cents if the test tubes and stirring rods are available. If not available the total cost need not exceed one dollar and a half for a class of thirty pupils. Bottles, tumblers or beakers could easily be substituted for the test tubes. The experiment can be carried on in almost any kind of a room. Certainly no elaborate equipment is needed. The cost is not prohibitive in any school. Many other practical problems may be solved in a similar way without the use of expensive equipment if teachers are interested in solving problems on an experimental basis. The solving of one problem usually introduces many other problems.

IS THIS THE SCIENTIFIC METHOD?

Does the plan followed here comply with the methods used by trained scientists? Are any important steps omitted? Are any unnecessary steps included? Does it follow the regulations of good experimentation? Does it help to train pupils to acquire a clearer understanding of the scientific method?

This experiment is described here with the hope that many other teachers will give illustrations of the procedures they use in helping pupils understand what the scientific method is.

BRIQUETTING COAL WITHOUT A BINDER

The Illinois State Geological Survey announces the publication of Report of Investigations No. 31, entitled *Briquetting Illinois Coals without a Binder by Compression and by Impact, A Progress Report of a Laboratory Investigation*, which will be available after November 1, 1933.

This investigation was undertaken in response to a serious problem confronting the coal industry of Illinois—that of putting fine coal into a marketable form. The general excess of fine coal over the market demand has always been an important handicap to the bituminous coal mining industry, a condition greatly accentuated by the increase in mechanized mining. The briquetting of fine sizes of bituminous coal has long been regarded as a means of preparing a superior type of fuel suitable for the increasingly exacting demands of the home heating market. This market, in the Illinois coal market area alone, consumes more than 30,000,000 tons annually.

This investigation explored the possibilities of preparing coal briquets, without a binder, by compression and by impact. The results of experimental work in the laboratory indicate that there is considerable promise of success in briquetting by the impact method and the results of these tests are presented and analyzed. Further investigation, particularly in regard to the effect of ash upon the quality of the briquet, effect of weathering upon briquets, and tests of their burning characteristics will be carried on. It is believed that eventually it will be desirable for the coal industry to inaugurate pilot plant tests.

The price of the report is 25 cents. Address requests to the Chief, Illinois State Geological Survey, Urbana.

PROBLEMS FOR RECREATION

By Clarence Radius
Chicago Junior College
and William Van Santen

The following list is to be looked upon as a compilation rather than a series of original problems. Suggestions as to type have been taken from such standard works as Licks' Recreations in Mathematics and Jones' Mathematical Nuts. In making this list the authors had in mind primarily teachers sponsoring Mathematic Clubs. However, the problems are not to be looked upon as amusement. Each is thought invoking and will cause the more alert student to muse. Some require very careful reading before they can be translated into the language of simple algebra. The latter type will be found useful in class work.

1. Write an even number using only odd digits.
2. A number of two digits is equal to twice the product of these digits. What is the number?
3. Five fours equal 55. How?
4. How can five nines be used to express the number 1?
5. How do four one's equal 12?
6. Using the digits of the numbers 11, 357, 357, 357 only once each, find five numbers whose sum is 19.
7. Four five's equal 100. How?
8. Use seven 9's to express 1000.
9. Use 1, 2, 3, 4, 5, 6, 7, 8, 9, 0 to express 100.
10. Use 1, 2, 3, 4, 5, 6, 7, 8, 9, 0 to express 1.
11. What three equal figures may be used to express 30? How?
12. How may 1, 2, 3, 4, 5, 6, 7 be added in rotation to total 100?
13. Use three equal figures to express 24. Do not use 8.
14. What number is it of which its double, its half, and its third are equal to 34?
15. What number added to itself gives the same number as its square?
16. Find two numbers such that their product equals their sum.
17. The difference between what two fractions is equal to their product?
18. Divide a number into four parts so that by adding 2 to the first part, subtracting 2 from the second, multiplying the third by 2, and dividing the fourth by 2, the result is the same in each case.
19. How can you find the sum of the numbers from 1 to 100 without adding them?
20. Complicated, yet simple. What is the number which multiplied by 3, then increased by $\frac{3}{4}$ of the product, divided by 7, diminished by $\frac{1}{3}$ of the quotient, multiplied by itself, diminished by 52, by extraction of the square root, addition of 13, and division by 5 gives the number 5?
21. How many quarter inch squares in a square inch? How many quarter inch cubes in a cubic inch?

22. Of a flock of geese on a lake, ten times the square root of the number departed at the sight of a cloud, an eighth part went to the woods, and six remained on the water. How many geese were there?
23. Ask a person to think of a number while you call it x, then ask him to multiply it by 2 and add 6 to the product; this gives you $2x+6$. Then ask him to square the number he thought of and add it to this, which gives you x^2+2x+6. Next he is to subtract five from this, giving you x^2+2x+1. He is now asked to take the square root of this, and you have $x+1$. If he gives you his result you immediately know the number he thought of. Endless exercises like this can be made by the use of simple algebra.
24. A newsboy asked one of his fellow newsboys how many papers he had left. "Figure it out" was the reply. "If I had as many more, and half as many more, and seven to boot, I would have 32." How many papers did he have?
25. Another newsboy he asked replied, "If I had as many more, and half as many more, and two and a half papers, I'd have 20." How many did he have?
26. A fruit dealer sold to his first customer half of his oranges and half an orange; to the second customer half the remaining oranges and half an orange; to the third customer half the remaining oranges and half an orange. He then had three dozen left. How many did he start with?
27. A farmer picks the square root of half the number of apples on a tree. 8/9 of the apples remain on the tree, and two had fallen to the ground. How many apples had there been on the tree?
28. Two men were walking along a railway track, each at the rate of three miles per hour, and in opposite direction. A passing train ran completely by one in 5 seconds and by the other in 6 seconds. How many feet long was the train?
29. How many rabbits and parrots are there in a pet store if the total number of heads and wings equals the total number of feet?
30. If three is one-third of ten, what is one-fourth of twenty?
31. "How many flowers have you picked" mother asked Ruth and Jane. "We left as many as we picked and as many as we did not pick we have." How many flowers did they pick?
32. A hog weighs 450 pounds when he stands on three feet. How much would he weigh standing on four feet?
33. If there are twelve one-cent stamps to a dozen, how many two-cent stamps are there?
34. If a brick balances three quarters of a brick and three quarters of a pound, then how much does the brick weigh?
35. Four cats and three kittens weigh 37 pounds. While three cats and four kittens weigh 33 pounds. What does a cat weigh? A kitten?
36. If three rails fence three acres, what will four rails fence?
37. A stone cutter cut a stone into four pieces so that any number of pounds from 1 to 40 inclusive could be weighed on the scale. What was the weight of each piece?
38. What will it cost to make six pieces of chain of four links each into one straight chain, if it costs three cents to cut a link and three cents to weld a link.

39. A farmer leaves his sons 17 horses to be divided as follows: $\frac{1}{2}$ to the oldest, $\frac{1}{3}$ to the next, $\frac{1}{9}$ to the next or youngest. How could they do it?
40. Two pints equals one-fourth gallon. 32 pints equals four gallons. Therefore 64 pints equals one gallon. Where is the fallacy?
41. One chicken has two legs, no (0) chicken has 1 leg. Adding member by member, one chicken has 3 legs. Where is the fallacy?
42. I bought a cork and a bottle for \$1.10, the bottle costing one dollar more than the cork. What did the bottle cost? The cork?
43. A and B place 21 coins on the table. A is to take 1, 2, or 3 coins, then B is to take 1, 2 or 3 coins. This is repeated until all the coins are taken. The one who takes the last coin is the goat. How can A always make B the goat, if B does not know the game?
44. In the above game how can B always make A the goat if A does not know the game?
45. All the coins in my pocket are dimes except two; all are nickels but two; all are quarters but two. How much money have I?
46. Two fathers and two sons bought tickets to a football game at fifty cents each. What was the total cost?
47. A employs B for four years offering \$1000 a year to start and either an increase of \$200 a year or an increase of \$50 every six months. Which should B take?
48. When butter was 13 cents a pound, how much could one buy for a cent and a quarter?
49. I sold my car for \$400 and bought it back for \$350. Then I sold it for \$450. How much did I gain?
50. A lady with \$1.00 wanted \$1.25. She pawned the \$1.00 for 75 cents and then sold the pawn ticket for 50 cents. She then had \$1.25. Who lost on the transaction?
51. If six dozen oranges cost as many cents as I can buy oranges for 50 cents, what are oranges worth per dozen?
52. Oranges cost 42 cents a dozen. If I bought 6 more for the same sum they would cost me 6 cents a dozen less. How many did I buy?
53. If 100 eggs cost as many cents as I can buy eggs for 64 cents, what are eggs worth per dozen?
54. In a bag are three five-dollar bills and one ten-dollar bill. How much should be paid for permission to draw a bill from it?
55. A man is twice as old as his wife was when he was as old as she is now. When she is as old as he is now, the sum of their ages will be 100 years. Find their ages now.
56. Reversing the digits of A's age gives B's age. The difference between A's age and B's age is twice C's age. B's age is ten times C's age. Find the age of each.
57. An auto is twice as old as its tires were when the auto was as old as the tires are. When the tires are as old as the auto is, the combined ages of the tires and the auto will be two years and three months. How old is the auto?
58. Four traveling salesmen leave their home office on the same day to make trips of 4, 8, 12, and 16 weeks respectively. If they keep on repeating these circuits when will they all meet at the home office again?
59. How often and when in 12 hours does the minute hand and hour hand coincide?

60. How long is it after the minute hand of the clock passes the hour hand after three o'clock until it is just opposite the hour hand?
61. Would the answer be the same if eight were substituted for three in the above problem?
62. A clock face is 1 foot in diameter. A cockroach can run 40 ft. per minute. If he starts counter-clockwise around the face at exactly twelve, how long will it be before he and the two clock hands are together again? How long will it be before he reaches the minute hand?
63. Two boys sit down to eat, one with 5 cakes and the other with 3, all the cakes having the same value. A third boy comes along and eats with them, paying 8 cents for his part of the meal. If they eat equally and consume all the cakes, how should the 8 cents be divided?
64. Jim and Jack begin to hoe two rows of corn. Jim does three hills on Jack's row and then begins on his own row. Jack finished his row and hoes 6 hills on Jim's row, when they find the work is finished. If the rows have equal number of hills, which man hoes the most and how much?
65. A girl goes to the dairy with two pitchers, one of which holds three pints and the other 5 pints. How can she bring back 2 quarts of milk?
66. If a rectangular lot is worth $640, what is a similar lot worth whose length and width are each 50% greater?
67. How many times does a clock strike in a day if it only strikes on the hour?
68. How many minutes is it until six o'clock if 50 minutes ago it was 4 times as many minutes past three o'clock?
69. If you add one quarter of the time from noon till now to half the time from now till noon to-morrow, you will have the exact time. What is the time?
70. "Why are wise few, fools numerous in the excesse?
'Cause wanting number, they are numberlesse."—Lovelace.

NEW JERSEY SCIENCE TEACHERS' ASSOCIATION

On November 18, 1933 the science teachers of New Jersey met at the State Teachers College at Montclair. At the general session in the forenoon two strong addresses were delivered:

"Adventures in Science" by Mr. Oliver Ajer, Research Laboratory, General Electric Company.

"Amphibian Life in New Jersey" (Illustrated by Motion Pictures) by Dr. G. K. Noble, American Museum of Natural History.

In the afternoon three section meetings were held: General Science, Biological Sciences, Physical Sciences. Papers were read by leading local teachers.

A glass blowing demonstration by the Scientific Glass Apparatus Company of Bloomfield was given after the section meetings.

Dr. Earl Glenn of the State Teachers College reports that all sessions were well attended and that the meeting was highly successful from every standpoint.

A PROPOSED COURSE IN BUSINESS ARITHMETIC

By H. E. Stelson
Kent State College, Kent, Ohio

Business arithmetic seems to have fared rather poorly among the courses presented in the high school. Those students who were not capable of carrying the regular work in high school mathematics have quite often been placed in a course in business arithmetic. Thus, this course has gradually acquired the reputation of an easy course in which only the worst dumb-bells could possibly fail. Authors apparently have constructed their textbooks with a view of supplying this demand. The result has been that the subject has in many cases fallen into disrepute with a decreasing number of schools offering the course.

Business arithmetic, the application of arithmetic to business (a broad term) is certainly in agreement with the present tendency of socializing or vitalizing the subject of mathematics. This should certainly be a primary objective in this course, but when such a course consists in a large measure of a review of the theory of grade school arithmetic, when half the course consists in repeating the work of addition, subtraction, division, multiplication, common fractions and decimal fractions (an easy review of arithmetic) and the other half in considering a few applications to about the same extent that they were originally taught in arithmetic, it is no wonder that the students' interest is not challenged and that they consider the course only a poor pastime.

Too often the teacher of business arithmetic adheres too closely to the textbook. There is no doubt that it is more difficult to teach business arithmetic than the more formal subjects of algebra and plane geometry. Not only must the teacher himself have a wealth of experience in business transactions but he must stimulate his students to improve their technique already established in arithmetic. And this last assignment is a difficult one. How many students after twelve years of age do actually improve their relative ability in penmanship, spelling or arithmetic and do not repeat the type of work represented by their original effort?

The business training and general value derived from business arithmetic should not be limited to the poorer type of student. There is certainly sufficiently difficult and interesting

material to benefit the brighter student. There is little use of teaching socialized mathematics to those who do not have the tools to apply the information to social mathematical situations.*

Suppose you ask the student who has taken a course in business arithmetic what he remembers about the content of the course. He will generally tell you that they studied addition and short cut methods. Short cut methods are very soon forgotten and very little used in actual practice. It is doubtful if the teacher uses short cut methods outside the classroom. Or how many check the addition of their grocery list by casting out nines or elevens?

The business arithmetic might best contain some material which will serve to review eighth grade arithmetic but this should certainly constitute a very short period of new and rather difficult problems. There is no subject presented in mathematical training which gives such a broad background and which covers such a wide field. Such a course might well present a brief introduction to such fields as statistics, finance, insurance, taxes, as well as other topics involving business practices. It would seem that this course would be valuable as a college preparatory course as well as for a strictly commercial course. Indeed, a good background in arithmetic is one of the best preparations for college mathematics.

The course which will be outlined can best be presented in the senior high school. The content of such a course might have the following chapter titles:

1. Fundamental Processes.
2. Percentage, Commission and Brokerage.
3. Trade and Cash Discount.
4. Business of the Home.
5. Averages and Graphic Presentation.
6. Square Root and Interpolation.
7. Insurance.
8. Investments.
9. Stocks and Bonds.
10. Taxation and Public Expenditure.
11. The Formula.

The first chapter should consist of a short review of arithmetic but with new and challenging problems. The chapters on

* See Mathematics Teacher, Vol. 23, p. 163 (1930).

percentage, commission and brokerage and trade and cash discount should be in accord with actual business transactions. The general theory should be carefully presented. The chapter on business of the home should present the more difficult problems of housewifery and personal budget making. The chapter on averages and graphic presentation might present the story of collecting mass data, assembling it in tabular form and interpreting the result by averages and charts such as is presented briefly in statistics. The chapter on square root and interpolation may explain how to extract square root by long hand methods and by tables and introduce the idea of reading between the lines in a table. This idea will be of value in insurance and finance.

The chapter on insurance should explain in detail such knowledge of casualty, automobile and life insurance that will be of benefit to the high school student. The student should be able to realize the purpose of the different types of insurance and their relative costs. The chapter on stocks and bonds should present a rather thorough introduction to this subject. The operation of the stock market should be discussed and a description of the different classes of bonds should be presented.

The chapter on investments should include a discussion of simple and compound interest, discount and a brief introduction to annuities. In the chapter on taxes the student should learn how taxes are collected and how public funds are spent. The formula is a chapter which deals with numerical substitution in formula. The formulas of algebra and those used in business arithmetic may be reviewed and correlated.

PROBLEM DEPARTMENT

CONDUCTED BY G. H. JAMISON
State Teachers College, Kirksville, Mo.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor, should have the author's name introducing the problem or solution as on the following pages.

The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to G. H. Jamison, State Teachers College, Kirksville, Missouri.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solution should observe the following instructions

1. Drawings in India ink should be on a separate page from the solution.

2. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

3. In general when several solutions are correct, the one submitted in the best form will be used.

LATE SOLUTIONS

1293. *Boris Garfinkel, Buffalo, New York.*
1295. *Boris Garfinkel, Buffalo, New York.*
1292. *Charles W. Trigg, Los Angeles, California.*
1298. *Proposed by D. Moody Bailey, Athens, W. Va.*

Determine x, y, and z so that $x^p y^q z^r$ shall be a maximum when $x+y+z=N$, if p, q, r, and N are positive constants.

Solved by W. E. Buker, Leetsdale, Pa.

Let $F=x^p y^q z^r = x^p y^q (N-x-y)^r$.

(1) $$\frac{\partial F}{\partial x} = x^{p-1} y^q (N-x-y)^{r-1}[p(N-x-y)-rx].$$

(2) $$\frac{\partial F}{\partial y} = x^p y^{q-1} (N-x-y)^{r-1}[q(N-x-y)-yr].$$

If $F(x, y)$ is to have a maximum or minimum, we set (1) and (2) each equal to zero and solve these equations for x and y.

We obtain $x=0$, $\frac{pN}{p+q+r}$ and $y=0$, $\frac{qN}{p+q+r}$ and by substituting these values of x and y in $N-x-y=z$, we obtain $z=0$, $\frac{rN}{p+q+r}$. Observe that when (1) and (2) equal zero, $x+y=N$ also.

The first set of values obviously yields a minimum. The last set of values gives a maximum.

Note. In a solution submitted by Mr. Charles Trigg, the values of $\frac{\partial^2 F}{\partial x^2}<0$, $\frac{\partial^2 F}{\partial y^2}<0$ and $\frac{\partial^2 F}{\partial x^2}\frac{\partial^2 F}{\partial y^2}-\frac{\partial^2 F}{\partial x \partial y}>0$ for the last set of values which is necessary to establish a maximum for F.

1299. *Proposed by Walter Penney, Union City, N. J.*

Find the value of

$$\sqrt{7+\sqrt{1+\sqrt{7+\sqrt{1+\sqrt{7+\cdots}}}}}.$$

Solved by Nathan Nicholson, Mathematics Club of South Philadelphia High School for Boys.

(1) Let $x=\sqrt{7+\sqrt{1+\sqrt{7+\cdots}}}$

Since $\sqrt{7+\sqrt{1+\sqrt{7}}}$ repeats itself, we can take away one of these radicals and we will still have the same thing left.

Squaring both members of (1) we obtain

(2) $x^2=7+\sqrt{1+\sqrt{7+\cdots}}$

(3) $x^2-7=\sqrt{1+\sqrt{7+\cdots}}$. Squaring both members of (3) we obtain

(4) $x^4-14x^2+49=1+x$

(5) Let $f(x)=x^4-14x^2-x+48$. Since $f(3)=0$, $x=3$ is a root of $f(x)=0$.

Evidently $x>7>2.6$. The other positive root of $f(\alpha)=0$ is approximately 2.3.

Also solved by Charles W. Trigg, Los Angeles, California, and a person whose name did not appear on the solution.

1300. *Proposed by W. E. Buker, Leetsdale, Pa.*

Find the volume of the tetrahedron whose edges are a, b, c, d, e, f.

EDITOR'S NOTE: No solution has been presented. The reader may find references to the problem in the *American Mathematical Monthly* June-July, 1921, pages 279–280 where values of V are given.

1301. *A solution to this problem will be offered in a later issue.*

1302. Given $a\triangle ABC$, $C=90°$. Construct within the $\triangle$ a point N such that $\angle ANB=\angle BNC=\angle CNA$.

Solved by Henry Luster, Mathematics Club of Simon Gratz High School, Philadelphia, Pa.

Construct on the outside of $\triangle ABC$ the equilateral $\triangle ABX$ and BCY. Circumscribe circles about these equilateral triangles. The circles intersect at B and N. N is the required point.

Proof:

$\angle ANB=120°$, also $\angle BNC=120°$. Hence $\angle ANC=120°$.

This construction applies to any triangle.

Also solved by Charles W. Trigg, Los Angeles, California, and W. E. Buker, Leetsdale, Pa.

1303. *Proposed by Charles W. Trigg, Los Angeles, California.*

A cow is tethered with a 100 ft. rope to a peg on the opposite side of a 10 ft. wall the peg being 20 feet from the wall. Find the area over which the cow can graze.

EDITOR'S NOTE: No solution has been presented. The reader is referred to the *American Mathematical Monthly* April 1919 pages 174–175 for a solution of a problem quite similar to this one.

1294. *Proposed by Chester Siddall, Philadelphia.*

If S_r^n denotes the sum of all the products r at a time of the first n integers it is found that

$$S_2^n=\frac{n(n^2-1)(3n+2)}{24} \text{ and } S_3^n=\frac{n^2(n+1)^2(n-1)(n-2)}{48}.$$

Find the formula for S_4^n and S_5^n. Also give a general solution if there is any for S_r^n.

Solved by Charles W. Trigg, Cumnock College, Los Angeles, Calif.

For any particular value of r, the general term S_r^n $(n=0, \cdots, n)$ may be found by use of Newton's formula. Since the calculations of the values, corresponding to large values of n, necessary for the derivation are laborious, it is convenient to use the identity,

$$S_r^n = S_r^{n-1} + nS_{r-1}^{n-1},$$

which is evident from the nature of the formation of the products. Thus, the fitst differences for r may be calculated by means of the formula for $r-1$. In the following table of differences for S_4^n, advantage has been taken of the formula given for S_3^n.

u_n	Δu_n	$\Delta^2 u_n$	$\Delta^3 u_n$	$\Delta^4 u_n$	$\Delta^5 u_n$	$\Delta^6 u_n$	$\Delta^7 u_n$	$\Delta^8 u_n$
$S_4^0=0$								
	0							
$S_4^1=0$		0						
	0		0					
$S_4^2=0$		0		24				
	0		24		154			
$S_4^3=0$		24		178		340		
	$4S_3^3=24$		202		494		315	
$S_4^4=S_4^3+4S_3^3$		226		672		655		105
	$5S_3^4=250$		874		1149		420	
$S_4^5=S_4^4+5S_3^4$		1100		1821		1075		105
	$6S_3^5=1350$		2695		2224		525	
$S_4^6=S_4^5+6S_3^5$		3795		4045		1600		105
	$7S_3^6=5145$		6740		3824		630	
$S_4^7=S_4^6+7S_3^6$		10535		7869		2230		
	$8S_3^7=15680$		14609		6054			
$S_4^8=S_4^7+8S_3^7$		25144		13923				
	$9S_3^8=40824$		28532					
$S_4^9=S_4^8+9S_3^8$		53676						
	$10S_3^9=94500$							
$S_4^{10}=S_4^9+10S_3^9$								

Substituting the values of the leading term and leading differences thus secured in Newton's formula,

$$u_x = u_0 + x\Delta u_0 + \frac{x(x-1)}{2!}\Delta^2 u_0 + \frac{x(x-1)(x-2)}{3!}\Delta^3 u_0 + \cdots,$$

the following expression is secured.

$$S_4^n = \frac{24n(n-1)(n-2)(n-3)}{4!} + \frac{154n\cdots(n-4)}{5!} + \frac{340n\cdots(n-5)}{6!} + \frac{315n\cdots(n-6)}{7!} + \frac{105n\cdots(n-7)}{8!}$$

$$S_4^n = \frac{n(n^2-1)(n-2)(n-3)(15n^3+15n^2-10n-8)}{6!\,8}.$$

In like manner, when $r=5$, the leading term and leading differences are found to be: 0, 0, 0, 0, 0, 120, 1044, 3304, 4900, 3465, 945. Whence,

$$S_6^n = \frac{120n \cdots (n-4)}{5!} + \frac{1044n \cdots (n-5)}{6!} + \frac{3304n \cdots (n-6)}{7!}$$
$$+ \frac{4900n \cdots (n-7)}{8!} + \frac{3465n \cdots (n-8)}{9!} + \frac{945n \cdots (n-9)}{10!}$$
$$S_6^n = \frac{n^2(n-1)(n-2)(n-3)(n-4)(n+1)^2(3n^2-n-6)}{6!16}.$$

In an endeavor to discover a general trend in these formulae, the leading term and leading differences for $r=6$ were found to be: 0, 0, 0, 0, 0, 0, 720, 8028, 33740, 70532, 78750, 45045, 10395. Whence

$$S_6^n = \frac{n(n-1)\cdots(n-5)(63n^6-2337n^5+95685n^4-1{,}524{,}539n^3+11{,}999{,}916n^2 - 46{,}857{,}364n+72{,}576{,}096)}{9!8}.$$

What the expression for the general solution, in terms of n and r, might be is not clear. However, if an expression or set of values for one value of r is available the values for $r+1$ may be calculated from the formula,

$$S_r^n = nS_{r-1}^{n-1} + (n-1)S_{r-1}^{n-2} + (n-2)S_{r-1}^{n-3} + \cdots + rS_{r-1}^{r-1},$$

which is derived from the original identity noted by successive substitution, and coupled with the evident fact that $S_r^n = 0$ when $n < r$.

HIGH SCHOOL HONOR ROLL

The editor will be very happy to make special mention of high school classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

For this issue the Honor Roll appears below:

1302. Nathan Nicholson. Mathematics Club of South Philadelphia H.S. for Boys. John Wills and David Davis, Lewis and Clark H.S., Spokane, Wash.

PROBLEMS FOR SOLUTION

1316. *Proposed by Franklin T. Jones, Cleveland, Ohio.*

An automobile license plate carries five figures all "ones" or "threes." If one of the figures was one greater, the number would be divisible by 31, and the quotient would be all "ones" or "zeros." In the quotient there are three figures alike. What is the number on the license plate?

1317. *Proposed by Charles W. Trigg, Cumnock College, Los Angeles, Calif.*

There are just three proper fractions, $\frac{26}{65}, \frac{16}{64}, \frac{19}{95}$, with denominators less than a hundred which may be reduced to lowest terms by illegitimately cancelling a digit. Are there any other proper fractions with denominators less than a thousand which may be reduced to lowest terms by illegitimately cancelling one or more digits? If so, identify them and prove that there are no others.

1318. *Proposed by O. F. Barcus, Columbus, Ohio.*

Extend one side, say CB, of equilateral triangle ABC to any point D. From D draw a line DF intersecting AB at E and AC at F. Show that triangle $AEF = \frac{1}{2}\triangle ABC$ when:

(1) $$DB = 0 \text{ and } AF = \frac{1}{2}AC$$

(2) $$DB = 2BC \text{ and } AF = \frac{2}{3}AC$$

(3) $$DB = 14BC \text{ and } AF = \frac{7}{10}AC$$

(4) $$DB = 84BC \text{ and } AF = \frac{12}{17}AC.$$

1319. *Proposed by W. E. Batzler, Battle Creek, Mich.*

Given two circles x and y with center of y on the curve of circle x. A triangle ABC is a variable triangle having its three sides tangent to the circle y and its vertices A and C on circle x. Find the locus of vertex B.

1320. *Proposed by Cecil B. Read, University of Wichita, Wichita, Kan.*

Each of the stories of a three story house is of equal height. A ladder with its foot x feet from the foot of the building (on level ground) just reaches the top. A second ladder, raised from the same point, reaches only to the top of the second story. If the second ladder is y feet shorter than the first, determine the height of the building.

1321. *Proposed by H. D. Grossman, New York City.*

Find the fallacy:

$$\log 2 = 1 - \tfrac{1}{2} + \tfrac{1}{3} - \tfrac{1}{4} + \tfrac{1}{5} - \cdots$$
$$\text{let } S = 1 + \tfrac{1}{2} + \tfrac{1}{3} + \tfrac{1}{4} + \tfrac{1}{5} + \cdots$$
$$\therefore \quad \log 2 + S = 1 - \tfrac{1}{2} + \tfrac{1}{3} - \tfrac{1}{4} + \tfrac{1}{5} - \cdots$$
$$+ 2(\tfrac{1}{2} + \tfrac{1}{4} + \tfrac{1}{6} + \cdots$$
$$= 1 + \tfrac{1}{2} + \tfrac{1}{3} + \tfrac{1}{4} + \tfrac{1}{5} + \tfrac{1}{6} + \cdots$$
$$= S$$

Hence $\log 2 = 0$, which is impossible.

SCIENCE QUESTIONS

January, 1934

Conducted by Franklin T. Jones, 10109 Wilbur Avenue, Cleveland, Ohio

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Please send copies of Tests and Examinations to Franklin T. Jones, 10109 Wilbur Avenue, Cleveland, Ohio.

LIBERTY QUESTIONS

638. *Liberty Magazine, 1926 Broadway, N. Y. paid $1.00 each for the following questions which were accepted for publication.*

1. Name the membrane which covers the lungs.

2. What is a "picul"?
3. What is a photometer?
4. What country bounds Denmark on the south?
5. What is an invertebrate?
6. What is a pluviometer?

ALUMINUM EXPLODES!!

From front page write-up in the Cleveland Plain Dealer October 6, 1933.

630. Can and will aluminum "explode?"

Something exploded. If aluminum did not explode, what did?

The reporter said—"The explosion occurred when the three (injured men) poured water on smouldering aluminum shavings."

The fire chief said—"Water on the hot metal generated a gas."

What gas and did the gas come from the aluminum?

Segal (one of the injured workmen) said, "I climbed to the top of a pile of barrels and bags and started to sprinkle the pile of shavings from a hose. A sheet of flame blew me 50 feet."

What is the real truth about this explosion?

Can some one write an equation?

Answer from Chemistry Class, Gilmer, Texas, through Marshall Brown, Instructor.

When given the question concerning the "explosion" of aluminum, several members of my chemistry class arrived at a conclusion which I take to be correct. I am sending a copy of a typical solution of the question for your approval.

We enjoy SCHOOL SCIENCE AND MATHEMATICS very much.

The explosion was caused by the violent reaction between hydrogen, which was liberated when the water came into contact with the hot aluminum, and the oxygen of the air. Aluminum is not active enough to liberate hydrogen from water at ordinary temperatures, but the metal being hot, the temperature was sufficiently high to liberate the gas rapidly:

$$2Al+6H_2O=2Al(OH)_3+3H_2$$

The hydrogen, mixed with the oxygen of the air, was ignited by the smouldering shavings which was the real cause of the explosion.

$$2H_2+O_2=2H_2O$$

639. *Submitted by A. H. Gould, Physics, Trade Science, Boy's Technical High School, Milwaukee, Wis.*

FINAL EXAMINATION IN PHYSICS I, JUNE, 1933

Using the numbered paper supplied to you for this purpose put down after each number an R or a W accordingly as you think that statement is right or wrong. Do not mark on this paper.

1. Efficiency in a simple machine is the distance the hand moves divided by the distance the load moves.
2. The velocity ratio of a differential hoist can be obtained by operating the machine without a load on it.
3. A cubic foot of stone weighing 162 pounds in the air will weigh 100 pounds when under water.
4. The pull of gravity on the helium in a balloon is just as great as it would be if the helium were reduced to a liquid.
5. A 15 pound piece of metal weighs only 12 pounds when under water. Its specific gravity is 3.

6. Archimedes' principle applies to balloons.

7. The large piston of an hydraulic press is 10 times as great in diameter as the small piston. A 50-pound pressure on the small piston will produce a 500 pound pressure on the large one, neglecting friction.

8. The jet of a carburetor is located at the neck or narrow part of a venturi tube. The air pressure here is greater than that in the outer atmosphere when air is rushing through.

9. Hooke's law applies only up to the elastic limit of materials and not beyond.

10. Concrete can stand tension better than compression.

11. A 50 pound piece of metal weighs 45 pounds when under water. Its specific gravity is 10.

12. The bottom fibres in a loaded iron beam take tension and those in the top take compression.

13. Approximately three quarters of the lift on an airplane results from the air currents against the under side of the wing.

14. Acceleration may be stated in feet per second or in miles per hour.

15. A bullet is accelerated in the rifle but travels at uniform velocity after leaving the rifle if we neglect air friction.

16. If you were to find the velocity of a falling body at the end of the 5th second the correct formula to use would be $V^2 = 2as$.

17. In one laboratory experiment we whirled a weight until it moved out against the action of a spring and we recorded the r.p.m. The purpose of this experiment was to determine the momentum of the weight.

18. The kinetic energy of a body equals WV^2/gr.

19. The tendency of a train to wreck itself on the outside of a curve is an illustration of Newton's first law or the law of inertia.

20. Neglecting friction, a 200 pound push against a 200 pound truck will give it an acceleration of 32 feet per second.

21. More heat is released when one pound of lead cools from 50 degrees C. to 20 degrees C. than when one pound of water cools through the same temperature range.

22. The heat released inside a steam radiator is due largely to the cooling of the hot steam down to 212 degrees F.

23. A fireplace heats a room largely by conduction.

24. Radiant heat cannot pass through a vacuum.

25. Infra red light is given off by a cup of hot coffee but hardly any is given off by hot coffee placed in a common thermos bottle or vacuum bottle of the common type.

26. A gram of steam condensing to water without any change in temperature gives up more heat than a gram of boiling hot water releases in cooling down to ice water.

27. Pressure cookers are used in Denver because it is difficult to make water boil at that altitude.

28. The low pressure coils of an iceless refrigerator are placed on the outside of the box and the high pressure coils inside.

29. When air is heated its relative humidity is lowered because some of its water vapor is driven off.

30. The lower the relative humidity the greater will be the difference in reading between the wet bulb and the dry bulb readings of the hydrometer.

640. *Submitted by H. K. Moore, Thos A. Edison School, Cleveland, Ohio.*

A Chemistry Test

Directions: Below are a number of incomplete statements. Five words or phrases are given after each statement. One of these five words or phrases makes the statement true; the other four are incorrect.

Read each incomplete statement carefully, decide which of the five possible words or phrases makes the truest sentence, then write the NUMBER (not the word or phrase itself) on the dotted line at the right, as shown in the sample.

Sample: When any substance burns, it units with

(1) hydrogen. (2) calcium. (3) oxygen. (4) soap. (5) iodine. (..3....)

.....

1. Water is composed of hydrogen and
(1) iodine. (2) oxone. (3) osmium. (4) oxygen. (5) zinc. 1. (.....)
2. Separating a substance into elements is known as
(1) decomposition. (2) oxidation. (3) electrolysis. (4) ionization. (5) iron. 2. (.....)
3. The expression NaCl is a (an)
(1) ion. (2) symbol. (3) equation. (4) radical. (5) formula. 3. (.....)
4. The chemical NaCl is a (an)
(1) ion. (2) element. (3) compound. (4) mixture. (5) solution. 4. (.....)
5. In a solution of water and sugar, water is called the
(1) solvent. (2) solder. (3) solute. (4) solid. (5) solution. 5. (.....)
6. The loss of water of hydration by exposure to air is known as
(1) absorption. (2) adsorption. (3) efflorescence. (4) deliquescence. 6. (.....)
7. Organic matter in water can be detected by means of
(1) $KMnO_3$ (2) NaCl (3) $KClO_3$ (4) $CaCl_2$ (5) KOH 7. (.....)
8. Water containing calcium may be clarified by adding
(1) sodium. (2) ammonia. (3) soap. (4) alum. (5) kerosene. 8. (.....)
9. Oxygen may be prepared by heating the oxide (ic) of
(1) iron. (2) mercury. (3) carbon. (4) sulphur. (5) sodium. 9. (.....)
10. Hematite contains oxygen and
(1) sodium. (2) zinc. (3) copper. (4) thorium. (5) iron. 10. (.....)
11. Oil treated with free hydrogen, using a catalyst, becomes
(1) soap. (2) water. (3) diastase. (4) methane. (5) fat. 11. (.....)
12. Our nickel coins contain nickel and
(1) copper. (2) zinc. (3) silver. (4) tin. (5) iron. 12. (.....)
13. A molecule of hydrogen may be expressed as
(1) H (2) H_2 (3) H_3 (4) H_4 (5) H_5 13. (.....)
14. An atom of hydrogen may be expressed as
(1) H (2) H_2 (3) H_3 (4) H_4 (5) H_5 14. (.....)
15. Which of these will turn litmus blue?
(1) NaCl (2) NaOH (3) HOH (4) HCl (5) $CuSO_4$ 15. (.....)
16. The process which takes place when an acid and base react is
(1) hydration. (2) analysis. (3) neutralization. (4) hydrolysis. (5) oxidation. 16. (.....)
17. An atom bearing an electric charge is called a (an)
(1) molecule. (2) salt. (3) ion. (4) electron. (5) proton. 17. (.....)
18. Which of these has negative valence?
(1) iron. (2) mercury. (3) sodium. (4) sulphur. (5) zinc. 18. (.....)

19. Which of these is an acid salt?
(1) washing soda. (2) blue vitriol. (3) borax. (4) white lead. (5) baking soda. 19. (.....)
20. The diamond is pure
(1) calcium. (2) glass. (3) carbon. (4) oxygen. (5) silicon. 20. (.....)
21. CH_4 is the formula for
(1) ethane. (2) methane. (3) propane. (4) butane. (5) pentane. 21. (.....)
22. The Bunsen flame is made luminous by glowing particles of
(1) carbon. (2) hydrogen. (3) iron. (4) sulphur. (5) calcium. 22. (.....)
23. C_2H_5OH is a (an)
(1) alcohol. (2) oil. (3) ester. (4) aldehyde. (5) organic acid. 23. (.....)
24. An ingredient of Castile soap is sodium
(1) oleate. (2) benzoate. (3) sulphate. (4) chloride. (5) tartrate. 24. (.....)

QUESTION RAISERS AND ANSWERS

All readers of SCIENCE QUESTIONS must know how difficult it is to have questions and answers that are really interesting to readers—teachers and students alike. Also, think of teachers and investigators in foreign lands who read SCHOOL SCIENCE AND MATHEMATICS and depend upon it for new ideas and ideas reflecting educational practice in the United States of America.

Accordingly, the **GUILD OF QUESTION RAISERS & ANSWERERS** (GQRA) has been formed by the SCIENCE QUESTIONS DEPARTMENT OF SCHOOL SCIENCE & MATHEMATICS.

You become a member when you send in a question, or an examination paper or an answer that is published.

NEW MEMBERS—JANUARY, 1934

11. Marshall Brown and Chemistry Class, Gilmer, Texas.
12. A. H. Gould, Boy's Technical High School, Milwaukee, Wis.
13. H. K. Moore, Thomas Edison School, Cleveland, Ohio.

FORMER MEMBERS

1. John C. Packard, Brookline, Mass.
2. Walter E. Hauswald, Beardstown, Ill.
3. Walter C. Pribnow, Sparta, Wisconsin.
4. William W. Johnson, Cleveland, Ohio.
5. A. G. Zander, Milwaukee, Wisconsin.
6. E. W. Bemisderfer, Cleveland, Ohio.
7. William Malkin, Cloverton, Minnesota.
8. Clyde W. Holt, Cleveland, Ohio (Lesson Unit on Metallurgy)
9. Senior Physics Class. The Norwich Free Academy, Norwich, Conn., Harold Geer, Secretary.
10. Carroll H. Lowe, Brookline, Mass.

Your name will be added as soon as your name appears as a contributor. Please help out with new or tried ideas—questions, tests, etc.

Note how classes from Norwich Free Academy and Gilmer, Texas contributed—the former by proposing Question 636 and the latter by answering Question 630!
Why not have your class get its name on the G.Q.R.A. list?
Send in your tests and questions!

BOOKS RECEIVED

High School Chemistry, by George Howard Bruce, Department of Chemistry, Horace Mann School for Boys, Teachers College, Columbia University. Revised Edition. Cloth. Pages x+550. 13×19 cm. 1933. World Book Company, Yonkers-On-Hudson, New York.

The New Day Junior Mathematics, Book Three, by Vevia Blair, Head of Department of Mathematics, Horace Mann School, Teachers College, Columbia University. Cloth. Pages xii+430. 13×18.5 cm. 1933. Charles E. Merrill Company, 381 Fourth Avenue, New York, N. Y.

Introductory Physics, by L. Grant Hector, Professor of Physics in the University of Buffalo. Cloth. Pages xv+373. 13.5×21.3 cm. 1933. American Book Company, 330 East 22nd Street, Chicago, Illinois. Price $3.00.

Brief Course in Plane and Spherical Trigonometry, by H. A. Davis, Assistant Professor of Mathematics, West Virginia University, Morgantown, West Virginia and L. H. Chambers, Instructor in Mathematics, West Virginia University, Morgantown, West Virginia. Cloth. 136+96 pages. 14×21.5 cm. 1933. American Book Company, 330 East 22nd Street, Chicago, Illinois. Price with Tables $2.00, without Tables $1.50.

How the World Lives and Works, by Albert Perry Brigham, Late Professor of Geology, Colgate University and Charles T. McFarlane, Formerly Professor of Geography, Teachers College, Columbia University. Cloth. Pages ix+406. 19×25 cm. 1933. American Book Company, 330 East 22nd Street, Chicago, Illinois.

Amateur Telescope Making, edited by Albert G. Ingalls, Associate Editor, Scientific American and Others. Cloth. Pages xii+500. 13.5×19 cm. 1933. Scientific American, 24 West 40th Street, New York, N. Y. Price $3.00 domestic, $3.35 foreign.

Handbook of Chemistry and Physics. Editor-in-Chief, Chas. D. Hodgman, M. S. 18th Edition. Cloth. 1818 pages. 10.5×17 cm. 1933. The Chemical Rubber Company, West 112th Street and Locust Avenue, Cleveland, Ohio. Price $6.00.

The Universe of Light, by Sir William Bragg, Honorary Fellow of Trinity College, Cambridge; Fullerian Professor in the Royal Institution of Great Britain. Cloth. Pages x×283. 14×21.5 cm. 1933. The Macmillan Company, 60 Fifth Avenue, New York, N. Y. Price $3.50.

Great Men of Science, by Philipp Lenard, formerly Professor of Physics and Director of the Radiological Institute in the University of Heidelberg. Translated from the second German edition by Dr. H. Stafford Hatfield with a preface by E. N. da C. Andrade, Quain Professor of Physics in the University of London. Cloth. Pages xx+389. 14×21.5 cm. 1933. The Macmillan Company, 60 Fifth Avenue, New York, N. Y. Price $3.00.

Provisions for Individual Difference, Marking, and Promotion, Bulletin, 1932, No. 17, Monograph No. 13, by Roy O. Billett. Paper. Pages ix+472. 15 x 22 cm. The Superintendent of Documents, Washington, D.C. Price 40 cents.

BOOK REVIEWS

Trees of North America (exclusive of Mexico) Vol. I—The Conifers, by George Rex Green, The Pennsylvania State College. Bound in flexible cardboard. 21×26 cm. 186 pages. Illustrated with one figure. 1933. Published by Edwards Brothers, Inc., Ann Arbor , Michigan. Price $2.00.

There are many tree books, but this volume is different. Professor Green has been a student and teacher of dendrology for many years. In this book he aims to give more than the botanical characters of tree. He has given much more—such as the moisture and soil requirements of the root systems of trees, the climatic range, economic uses, distribution, abundance, adaptability to cultivation and reforestation, light requirements, the tree in the open and on lawns, ability to reproduce itself, etc. The book therefore will have a wider range of usefulness than the usual tree book for example, to city foresters and shade tree commissioners and for determining the soil and moisture requirements of trees in new plantings. It is worthwhile to know what species of trees may be planted in any particular type of soil.

This volume on Conifers is to be followed by a volume on the Broadleaf trees. The lack of illustrations is not important because the author is not emphasizing the morphological characters of trees. There is an abundance of tree books amply illustrated for the use of students of forestry, but few books offering what is contained in this book.

W. WHITNEY

Sex in the Plant World, by Wilfred W. Robbins, Ph.D., University of California and Helen Monosmith Pearson, Ph.D., University of California. Cloth. 13×19 cm. Illustrated with 66 figures. 5+187 pages. 1933. Published by D. Appleton-Century Company. Price $2.00.

This book is a pleasant and timely surprise. The more we studied the book the greater was our liking for it. Heretofore sex has been treated incidentally and sketchily in general textbooks of botany. We have now a book which outlines the subject of sex in plants in an orderly fashion through the entire plant kingdom. The treatment of the subject is thoroughly scientific and scholarly, as we might expect from Professor Robbins. But in addition, it is very clear and readable—and intelligible to laymen who have not the advantage of a scientific training in botany.

The books begins with a chapter on the biogenetic law—"all life from life." Next the discussion takes up sex in flowers, ferns, and mosses and the origin of sex. Later there is discussion of such subjects as "primitive sex"; "parthenogenesis"; "plant courtships"; "sex traits"; "how plants prevent inbreedings"; "sex chromosomes" and other topics equally interesting. The treatment of these topics is scientific and up to date and is moreover couched in a simple English style that makes the reading very enjoyable.

The drawings are partially diagrammatic to make them clearer and more understandable for the lay reader, explaining the text which they illustrate. We bespeak for this book popularity among students of botany and teachers of botany in secondary schools.

W. WHITNEY

Plants Useful to Men, by Wilfred William Robbins, University of California and Francis Ramaley, University of Colorado. Cloth. 14×21 cm. pages v+423. 241 figures. 1933. Published by P. Blakiston's Son and Co., Inc. Price $3.00.

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SCHOOL SCIENCE and MATHEMATICS

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A very useful book by the author of Botany of Crop Plants. It is not intended to function as an exhaustive study of economic plants, but rather as briefer text for a short term study of useful plants by college classes, and as a reference text for high school teachers and others interested in this subject. A portion of the material is taken from the author's Botany of Crop Plants.

The discussion begins with a chapter on the sources of cultivated plants, a very interesting chapter, listing plants used by prehistoric peoples dating back more than 4000 years. Then follow in ascending order discussions of plant families beginning with the lower plant groups, and proceeding by successive chapters to the highest orders of plants. The treatment of each family is systematic and comprehensive, emphasizing the scientific importance as well as the economic importance of the useful plants in the family.

The book is well illustrated by photographs and drawings. We feel that the book will serve a very useful purpose for high school teachers of botany as a reference book, but especially as a means of supplementing the regular work of classes with interesting additional material.

W. WHITNEY

Handbook of Chemistry and Physics. Editor-in-Chief, Chas. D. Hodgman, M. S. 18th Edition. Cloth. 1818 pages. 10.5×17 cm. 1933. The Chemical Rubber Company, West 112th Street and Locust Avenue, Cleveland, Ohio. Price. $6.00.

Bigger and better each year seems to be the guiding principle of the Handbook editor. The first edition made its appearance twenty years ago and was at once recognized as a valuable reference book for all science students and investigators. The coöperation of scientists and teachers was enlisted and their suggestions and criticisms have been assorted and evaluated for use in making improvements in each of the seventeen editions that have followed. Now the Handbook is indispensable. No science library is complete without it; every student of physical science early in his course should form the habit of consulting it. The wealth of material, the compact and accessible arrangement, and the superior mechanical structure will retain for the Eighteenth Edition its convenience and durability under constant use even though it contains more than 1800 pages.

Some of the revisions are the addition of nearly a thousand new compounds to the Table of Physical Constants of Inorganic Compounds and the addition of new data to those previously listed; new descriptions of the elements including those recently discovered; complete revision of the table of Characteristics of Thermionic Tubes; additional data on isotopes, speed of plates and films, pH values for potentiometer readings, optical rotation of acids and bases, solubility chart, etc. Several new tables have been added and minor corrections made where needed.

G. W. W.

A Textbook of Physics, Vol. II—Heat and Sound, by E. Grimsehl, edited by R. Tomaschek and translated from the Seventh German edition by L. A. Woodward, Cloth. Pages xi+312. 14.5×22 cm. 1933. Blackie and Son, Limited, 50 Old Bailey, London, E.C. 4. Price 12s. 6d. net.

This book follows the general plan of Vol. I—Mechanics reviewed in the October 1933 issue of this journal. Although the discussion of heat occupies only 188 pages, yet by use of small type for descriptions of experiments, historical paragraphs, and even some of the theory the author is able to give a fairly comprehensive treatment. The text passes rapidly over the discussions of thermometry, calorimetry and transfer of heat but

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gives a quite thorough treatment of kinetic theory, change of state, and thermodynamics.

An excellent fifty page section on vibrations and wave motion gives all the foundation material for a study of sound and the other divisions of physics based on wave motion. The actual discussion of sound is, however, very brief and inadequate. Recent research in this field has been entirely omitted.

An interesting and valuable feature of the text is the series of biographical footnotes. As each investigator is first mentioned a short footnote tells briefly of his chief contributions. The book is an excellent reference for students and teachers and a worthy companion to Vol. I.

G. W. W.

Wild Wings, by Julie Closson Kenly. Cloth. Pages xiv+275. 13×20.5 cm. 1933. D. Appleton and Company, 35 West 32nd Street, New York, N. Y. Price $2.50.

This is a delightful book filled with interesting stories of bird life, startling facts about their characteristics and accurate descriptions of their habits, their eggs and their nests. The author has evidently made a thorough study of birds and has a style of expression that makes even ordinary incidents interesting. No attempt has been made to include all kinds of birds but types have been selected from among the common birds that all can observe. It is a book that all children will like. Read it aloud to them. It will make bird-lovers of all of them.

G. W. W.

Molders of the American Mind, by Norman Woelfel. New York, Columbia University Press, 1933. Pp. 304. $3.

This book, dedicated to "The Teachers of America," consists of four sections. In the first Dr. Woelfel discusses the factors accounting for the decline of present-day social institutions, and points out the resources which may be utilized in the process of social reconstruction. In the second section he takes up those American educators who have stressed in their writings and even more in their teachings the traditional elements and techniques in our culture. The third section is devoted to the educators who have assumed science to be the basis of cultural orientation. In the fourth, and last, section Dr. Woelfel aims to bring out the social and educational problems of experimental naturalism, and offers a program of suggested procedures which should, if followed, serve as a guarantee of enlightened progress. The book is well written and well organized. It has a definite professional appeal to every educator, and should be acquired by the school libraries of every hamlet, town, and city in the country. Many teachers, conscious of their problems, will want to possess their own copies as well.

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